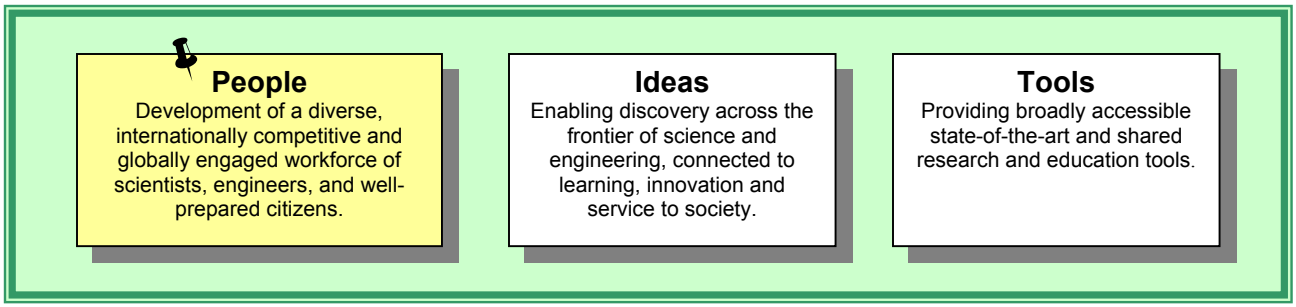
IV. NSF OUTCOME GOALS

A. PEOPLE



PERFORMANCE OUTCOME GOAL III-1a: Development of "a diverse, internationally competitive and globally engaged workforce of scientists and engineers, and well-prepared citizens."

✓ Goal Achieved

To achieve this outcome, we invest in the best and brightest students, researchers and educators to ensure a well-prepared workforce and citizenry. We provide support for formal and informal science, mathematics, engineering and technology education at all levels – pre K-12, undergraduate, graduate – in addition to professional development and public science literacy projects that engage people of all ages in life-long learning. Our efforts must serve as a catalyst and a test bed for a gradual change in the process and philosophy of educating the workforce. This is particularly true of science education at K-12 level, given the small fraction of total resources in K-12 education represented by NSF funding.

Goal III-1a is a new performance goal for us. Our performance for this goal is successful if *assessments from external evaluators* find that results we reported for the period FY 2001 demonstrate significant achievement for one or more of the following indicators:

- Improved mathematics, science, and technology skills for U.S. students at the K-12 level, and for citizens of all ages, so that they can be competitive in a technological society;
- A science and technology and instructional workforce that reflects America's diversity;
- Globally engaged science and engineering professionals who are among the best in the world; and
- A public that is provided access to the benefits of science and engineering research and education.

RESULT FOR PERFORMANCE GOAL III-1a: Reports prepared by external experts provided examples of significant achievement in reports they developed during FY 2001 reporting. A number of reports indicate that further improvement is needed in activities related to diversity.

Implications for the FY 2002 Performance Plan: This goal will be continued in FY 2002. The set of performance indicators related to the People goal has been expanded and modified to appropriately reflect the breadth of NSF activities (See Section X. for details).

INDICATOR 1: Improved mathematics, science, and technology skills for U.S. students at the K-12 level, and for citizens of all ages, so that they can be competitive in a technological society.

RESULT: ***Demonstrated significant achievement. Examples follow.***

SYSTEMIC ACTIVITIES

Systemic Reform: This combination of programs [Statewide Systemic Initiatives (SSI), Rural Systemic Initiatives (RSI), Comprehensive Partnerships for Mathematics and Science Achievement (CPMSA)] address state, region, and school district science, mathematics, engineering, and technology (SMET)[6] education. While it is difficult, if not impossible, to directly attribute the changes in U.S. SMET education solely to the Educational System Reform (ESR) programs, the ESR programs clearly contributed to these changes. First, the notion of systemic reform now permeates SMET education, and education in general. Prior to the SSI, RSI, and the CPMSA programs, improving SMET education was not characterized as a systemic problem. These programs were the first to recognize that the typical strategies used by school districts or state departments of education to increase SMET achievement were not sufficient to produce high-quality SMET education for all students. Second, these programs made improvement of mathematics and science education a priority issue for K-12 education. This combination of programs focused the attention of school districts, states, and other institutions on improvement of mathematics and science education and prompted these institutions to allocate resources to this issue. Third, these programs made serving all students a national mandate. The importance of SMET education for all students, including those from groups traditionally underrepresented in SMET jobs and careers, is now widely recognized. Though bridging the achievement gap between students from traditionally underrepresented groups and other students remains a significant challenge, the importance of addressing this problem is firmly established.

In the following paragraphs we highlight statements and quotations taken directly from reports of the FY 2001 COVs (Committees of Visitors) on NSF systemic programs.

Student Achievement:

The vast majority of the USI/CPMSA programs has shown significant increases in the number of students participating and succeeding in gatekeeper courses. In mathematics over the period 1993-1998 the average annual increase for students enrolling in these courses is about 9% and the annual increase of successful mathematics completions during this time was about 7%. In science during the same period enrollment increased about 7% annually and completions increased by 8% annually, which is excellent.

Except for Cohort I, the RSI have not been in effect long enough for program-wide evidence of substantial student achievement gains to materialize. The RSI program has made significant progress in building the capacity and infrastructure of rural districts to

[6] In our report one will find the acronyms SMET (Science, Mathematics, Engineering, and Technology) and STEM (Science, Technology, Engineering and Mathematics). The two acronyms are equivalent. External experts used one or the other of these terms.

understand, initiate and sustain mathematics and science reform. This action should result in increased student achievement. Given the initial state of RSI districts—poor rural districts with few resources to initiate and support reform efforts or to provide challenging educational opportunities to students—the focus on building infrastructure and capacity is the appropriate starting point for reform efforts.

Of particular note are the achievement gains made in the Puerto Rico SSI, the Louisiana SSI, and the Massachusetts SSI…For the Massachusetts SSI, we find that over the last three years, the trend has been of increased enrollment in all AP classes among all populations. About 79% of the more than 12,000 students taking AP courses also took the Advanced Placement (AP) exam, of which over 71% achieved a score of 3 or better on the exam. The Calculus enrollment (both AB and BC) has received the more robust raises with more than a 50% increase in the African American population and a third in the Hispanic population. The passing rates among students taking Calculus are also superior (ca. 73% for the first course and 90% for the second course).

Curriculum Implementation:

Five RSI projects have been in effect for three of more years (Alaska RSI, Appalachian RSI, Delta RSI, Tribal Colleges RSI, Navajo Nation RSI). Some evidence of improvement in mathematics and science achievement is beginning to emerge from these RSI projects. For example, the SAT9 test scores of Arkansas students in schools in which the Delta RSI has worked intensely have increased substantially compared to those in other Delta districts and the state overall (DRSI 2000 Annual Report). Similarly, 94% of the Appalachia RSI (ARSI) “Catalyst Schools” are showing improvements in state assessment results relative to comparison schools in non-participating districts (ARSI 2000 Annual Report). And the Alaska RSI (AKRSI) reported increases in college enrollment (from 36 students in 1994 to 70 students in 1998) by Alaskan Native students from AKRSI districts

“The RSI have been particularly effective in the area of standards and curricula. All RSI have increased awareness of national mathematics and science standards; most have played key roles in state and district standards development. For example, the Alaska RSI (AKRSI) was responsible for the development of state science as well as mathematics standards as well as providing professional development about these standards. (Initially, the state department intended to create only mathematics standards.) … Most notably, RSI working with indigenous populations (AKRSI, Navajo Nation RSI) have developed culturally sensitive instructional materials that integrate the knowledge base of indigenous peoples with western science.”

The RSI have focused their limited resources to develop the knowledge base and leadership capacity of teacher leaders and district administrators, and have worked intensively with a subset of "catalyst schools," schools that, for a variety of factors, were most poised to implement standards-based mathematics and science programs. The most recent annual reports of the five RSI indicate the increased capacity of teacher leaders and teachers in “catalysts schools” to implement standards-based mathematics and science instruction. For example, ARSI reported substantial increases in the percentage of “catalyst schools” with standards-based mathematics and science curricula (from 29% pre-ARSI to 79% in 1999), with instructional materials aligned to curricula (from 31% pre-ARSI to 86% in 1999) and extent of implementing inquiry-based teaching (10% pre-ARSI to 75% in 1999).

A key element to the success of the CPMSA investment is geared toward the partnerships that have been established. These relationships not only provide support for students and teachers but also increase community awareness of the efforts of the CPMSA and its influence on science and mathematics teaching and learning. Eligible activities under this initiative include research-based professional development for teachers; summer institutes for teachers; research-based internships and/or mentorships for students; and tutorial programs involving graduate/undergraduate students. In one site, the Partners in Education/Adopt A School Project has attracted 250 volunteers to assist with mentoring students. CPMSA sites are all involved in developing standards-based curricula. Progress in this area varies from the developmental phase to clearly defined time schedules. There is indication that these efforts incorporate National Council of Teachers of Mathematics (NCTM) standards; National Research Council (NRC) National Science Education Standards; and state Mathematics and Science Frameworks. The sites appear to be demonstrating more progress toward implementation at the lower grades than at the higher grades.

NON-SYSTEMIC ACTIVITIES

The **Show-Me** Center, the Implementation and Dissemination Site for middle-school mathematics curriculum: (a) has had approximately 35,000 hits on its Website (http://showmecenter.missouri.edu) that is estimated to reach approximately 250 new users each week; (b) conducted a Leadership Conference attended by nearly 400 state and national leaders in mathematics education seeking information on the curricula; and (c) gives presentations at local, state, and national teacher and professional society conferences.

The Leadership and Assistance for Science Education Reform Center (**LASER**), the dissemination site for K-8 science curriculum, exceeded its five-year goal within its first 3.5 years of operation. It has disseminated and helped to implement NSF-supported curriculum materials in over 300 school districts, serving some 1,000,000 K-8 students nationwide.

The Teachers Experiencing Antarctica and the Arctic (TEA): K-12 teachers who join a research team in Antarctica or the Arctic post daily electronic journals for their students and develop teaching materials for classroom use. Fifteen teachers participated in the program in the year 2001. NSF also supported a program for K-12 Teacher Training in Arctic Science. A partnership between the University of Texas at Austin Marine Science Institute and the Port Arkansas Independent School District provided training for K-12 teachers on Arctic science, including topics such as climate, sea ice, ozone depletion, and human adaptations.

IRIS Education: The Education & Outreach (E&O) Program of the IRIS Consortium runs one-day workshops that train both pre-service and in-service K-12 teachers. IRIS uses a two-pronged approach to reach the K-12 teacher population: directly through workshops held at national professional scientific and education meetings, and by training seismologists in the research community to run teacher workshops and then providing these seismologists with the resources to run a workshop locally. The IRIS E&O Program has placed high priority on development of educational materials that can be used at all levels. One-page handouts and posters have been distributed to a wide audience worldwide that includes research scientists, college and K-12 educators and their students, and the public. Over the past two years, more than 15,000 handouts and posters have been distributed nationally and internationally upon request, with a similar number distributed at national and regional scientific and educational meetings. Both English and Spanish versions of the one-pagers have been developed (http://www.iris.washington.edu/EandO/onepager.html).

INDICATOR 2: A science and technology and instructional workforce that reflects America's diversity.

RESULT: ***Demonstrated significant achievement. Examples follow.***

Distributed Mentor Project: The primary goal of this project is to increase the number of women entering graduate school in Computer Science and Engineering (CS&E) by involving them in research at a university with a female mentor. Each year, approximately twenty undergraduate women have participated in the research and mentoring activities of the Distributed Mentor Project (DMP). The students are involved in research, learn how a research university operates, meet graduate students and professors, and get a chance to observe a successful female researcher first hand. A longitudinal evaluation study of the project is being conducted by the Learning through Evaluation, Adaptation, and Dissemination (LEAD) Center of the University of Wisconsin[7].

The longitudinal evaluation shows the DMP project to be spectacularly successful at meeting its goal of increasing the number of women entering graduate school in CS&E. Using a Baccalaureate & Beyond study conducted in 1994 as a comparison, the best male CS&E graduates were 10 time more likely to enter graduate or professional school within one year of graduation than the best female CS&E graduates; the figure for men being 29.19% of graduates, for women being 2.53% of graduates[8]. Of the DMP participants, over 50% were enrolled in graduate or professional school the year following their graduation. In both cases the surveys considered only graduates with Grade Point Averages (GPA) greater than or equal to 3.5.

One successful program that provides a "pipeline" to bring ethnically diverse undergraduates into careers in the atmospheric and related sciences **Significant Opportunities in Atmospheric Research and Science (SOARS):** SOARS resides at the National Center for Atmospheric Research (NCAR) and identifies, recruits, and provides students attending colleges/universities in the U.S. and Puerto Rico with multi-summer research experiences, year-round guidance, counseling, and mentoring, and up to two years of graduate school support. SOARS boasts an 82% retention rate. Since its 1996 inception, 62 students/protégés have participated. Forty-two are current participants, nine are alumni and 11 have left the program. To date 38 have completed bachelor's degrees in a science field, 17 are enrolled in atmospheric or related science graduate programs, three are American Mathematical Society (AMS) graduate fellows, nine have completed master's degree programs, and three are Ph.D. candidates. No protégé has left college/university without completing an undergraduate degree in science, mathematics or engineering. Seven protégés have co-authored nine papers published in refereed journals. Many protégés have presented papers and posters of their summer research results at numerous regional, national, and international professional conferences; two papers received best presentation awards, one paper received an honorable mention; one poster was awarded best poster in atmospheric science. Six alumni are in the scientific workforce; three are enrolled in Ph.D. programs.

Louis Stokes Alliances for Minority Participation (LSAMP): Increased efforts are underway to keep more of the Science, Technology, Engineering and Mathematics (STEM) graduates

[7] "*Distributed Mentor Project: Comprehensive Participant Survey Analyses for 1994-1999*", The LEAD Center, University of Wisconsin-Madison, Preliminary Report, March 2000.
[8] "*Baccalaureate and Beyond; Longitudinal Study*", National Center for Educational Statistics, 1994.

from LSAMP institutions in the graduate school pipeline. There is a Bachelor of Science/Master of Science (BS/MS) program involving several institutions in the Atlanta area: Emory University, Georgia Institute of Technology, Georgia State University, Morehouse School of Medicine, and the colleges of the Atlanta University Center. Other initiatives focus on providing better linkage of the NSF-funded undergraduate programs with NSF-funded graduate programs. Attention to making the early STEM curriculum more student-friendly is underway in programs at several universities including the one at North Carolina A & T State University in Greensboro, NC, which focuses on tackling the three introductory "killer courses" in chemistry, mathematics, and physics. Other initiatives are taking place in the Historically Black Colleges and Universities Undergraduate Program and include one at Jackson State University to revise the teaching of calculus to include technology and laboratory experiences. At Morgan State University the initiative emphasizes research experiences for the STEM students.

The **Advanced Technological Education (ATE)** program contributes to broadened participation by under-represented minorities, as well as general improvement of technological education, through its focus on community colleges. Community colleges are where a large fraction of minority students begin their higher education. For example, the American Association of Community Colleges is conducting a series of activities designed to advance community colleges' leadership in STEM education. These activities include organizing an annual conference for ATE Principal Investigators; organizing a "Summit on Technological Education" that will bring community college and business representatives together to develop strategies to strengthen the nation's technical workforce and faculty pipeline; and continuing a successful mentoring program that helps community colleges establish new programs in STEM by pairing them with colleges that have already developed exemplary programs.

"Team-Mentoring: Catapulting Women through the **Glass Ceiling**" refers to an innovative and very successful mentoring conference for 40 junior women economists supported by NSF. The conference accomplished its goal of improving the research, grant writing, networking, and life balancing skills of the 40 junior women economists. It also produced conference plans, supporting materials and a video that so far have been used to hold four more mentoring conferences for women in economics. The American Economic Association Summer Training Program is an intensive eight and one-half week program designed to encourage and prepare talented undergraduates for success in economics doctoral programs. This is combined with a Scholarship Program that recruits, selects and funds under-represented minority (Black, Hispanic and Native American) participants who are U.S. citizens or permanent residents. Recent statistics show that the Summer program has been very successful in raising the numbers of minority students in strong graduate programs.

The **Gateway Coalition** alters engineering education from a focus on course content to the development of human resources and the broader experience in which individual curriculum parts are connected and integrated. The scope of the program includes four major parts: curriculum structure, human potential development, instructional technology and methodology, and evaluation measures. Gateway efforts aim at increasing the numbers of women, underrepresented minorities and the disabled participating in engineering; and drawing engineering faculty to a dedicated investment in the teaching of undergraduate students. During the period in which the Gateway Coalition was established, the retention of African American engineering students from the freshman to the sophomore year in the Gateway Coalition universities increased from 67% in 1992 to 87% in the year 2000. For women students, this retention increased from 75% to 90%, and for all engineering students retention increased from 79% to 86%.

INDICATOR 3: Globally engaged science and engineering professionals who are among the best in the world.

RESULT: ***Demonstrated significant achievement. Examples follow.***

Costa Rican Biodiversity Laboratory: A collaborative project involving the ALAS (Arthropods of La Selva) research team, the Organization for Tropical Studies (OTS), and the Instituto Nacional de Biodiversidad (INBio, Costa Rica) has produced an inventory of tropical rainforest insects at the La Selva Biological Station, Costa Rica, (a biodiversity laboratory) and trained a staff of parataxonomists drawn from local citizens, who conduct research and give tours. ALAS is highly visible to the public. The ALAS lab is a magnet for La Selva visitors, including local school children, U.S. senators, and Latin American decision-makers. ALAS was the subject of a New York Times ('Science Times') article (Yoon 1995), a live telecast from La Selva by Turner Educational Services, and a Nova-like segment on the Japanese Television Workshop. ALAS has been featured in Costa Rican television programs and newspapers.

International Geotechnical Activities: In addition to promoting the internationally-linked engineering research activities, NSF has been proactive in fostering international initiatives and collaborations-at-a distance. An example is the geotechnical reconnaissance report on Hyogoken-Nanbu earthquake. Eighteen U.S., Japanese, and Canadian researchers were rapidly deployed in the area affected by the Hyogoken-Nanbu earthquake to prepare a document that was of substantial value to U.S. practitioners and researchers. The report was available on the Web shortly after the earthquake. The work represented exceptional international collaboration and provided invaluable reconnaissance training for young researchers. They have become leaders of the reconnaissance efforts that took place following major earthquakes in Turkey, Taiwan, and Washington State.

David Dobson of Texas A & M University received the first **Felix Klein prize** awarded by the European Mathematical Union. The award, made in June 2000, recognized Dobson for his work to design light-diffracting structures for use in devices such as laser instrumentation and optical communications equipment. The early part of this work was supported by an Industrial Postdoctoral Fellowship and by a Mathematical Sciences Postdoctoral Research Fellowship, both funded by NSF.

NSF supports very high quality, field programs in **global meteorology**. The Dynamics and Chemistry of Marine Stratocumulus (DYCOMS) program was a study of cloud microphysics, boundary-layer entrainment, and evaluation of the applicability of large-eddy simulation modeling of the coastal marine boundary layer. In addition to the US participants, DYCOMS included researchers from France and Poland. The Physical Meteorology (PMET) also contributed to support of the Cooperative Atmosphere-Surface Exchange Study-1999 (CASES-99) observational program, led by the Army Research Office and conducted in Kansas. CASES-99 sought to provide a testbed for obtaining high quality, comprehensive boundary layer and hydrological measurements in a small watershed in order to probe the structure of the nocturnal boundary layer and to seek to close the water balance in a small watershed. In addition to numerous US investigators, CASES-99 also involved European scientists from Scandinavia, Spain and the Netherlands.

International Plant Genome Collaboration: One investigator was involved in establishing workshops at the International Triticeae Mapping Initiative, involving a variety of genome and Expressed Sequence Tags (EST) projects related to the cereal crops, especially projects in Europe and Australia. Two others have collaborations with the International Rice Research Institute in the Philippines, and one of these also has formal collaborations with groups in Japan and Brazil. Another investigator heads up a project that has become the hub for research on the model legume system Medicago truncatula. This activity includes collaborations at the Centre National de Recherche Scientifique/Institut National de la Recherche Agronomique (CNRS/INRA) in France, the Agricultural University of Wageningen, the Netherlands. Another investigator has active collaboration with scientists at the Friedrich Miescher Institute in Basel, Switzerland.

Frederick Brooks of the University of North Carolina (http://www.cs.unc.edu/~brooks/) received the **Turing award**, the highest honor in computer science, in February 2000 for "landmark contributions to computer architecture, operating systems, and software engineering." Dr. Brooks is now working primarily in the areas of computer graphics and supported in part by an NSF grant. This enables him to work on "Real-Time Walkthroughs of Serious Synthetic Environments" (http://www.cs.unc.edu/~walk/). The goal of this project is to create interactive computer graphics systems that enable a viewer to experience an architectural model by simulating a walk through of the model. While Dr. Brooks supplies much expertise for the integration of the system, other team members have made fundamental advances in computer graphics. This includes collision detection – for which Dinesh Manocha of the University of North Carolina (http://www.cs.unc.edu/~dm/) won the Best Paper award at Eurographics in 1999 – simplification of models for visualization, and image-based rendering.

INDICATOR 4: A public that is provided access to the benefits of science and engineering research and education.

RESULT: ***Demonstrated significant achievement. Examples follow.***

Explore the Universe: NSF is supporting the creation and installation of a major new permanent exhibit, *Explore the Universe*, in the Smithsonian Institution's National Air and Space Museum. This exhibit, opened in September 2001, provide the 9 million annual visitors to the Air and Space Museum with a perspective on how our understanding of the Universe has changed over time as the tools we use to study it have evolved. The exhibition makes use of a selection of artifacts, working models, images, interactive videos and computer programs, hands-on exhibits, and live demonstrations to explore scientists' view of the Universe as well as how they use ground- and space-based technology to study it.

Nanoworld 'Picture Books': To bring the nanoworld to everyone, the University of Wisconsin Materials Research Science and Engineering Center has developed a series of short web-based 'picture books' accompanied by hands-on demonstrations that illustrate nanoscale materials and devices. This work is the basis for a lead article in the Smithsonian's *Muse* magazine Spring 2001 issue dedicated to nanotechnology.

The American Association for Microbiology's Microbial Literacy Collaborative produced a four-part TV series that was viewed by 1.6 million households each week. As of June 2000, twenty thousand copies of this project's publication of hands-on activities, "**Meet the Microbe**," had been distributed nationwide (over half to individuals and organization upon specific request), and an additional 17,000 activities were downloaded from the www.microbeworld.org web site. This Website received 689,620 hits and recorded visits by nearly 29,800 individuals during its first month, and received over 3 million hits in its first year.

For the last fifteen years, the NSF and the United States Geological Survey (USGS), along with private foundations and universities, have made significant investments in development of the Global Seismographic Network (GSN) and its associated data collection facilities. **The Incorporated Research Institutions for Seismology (IRIS)** Consortium, in collaboration with the USGS, has begun to exploit this scientific resource for educational purposes, by making data from the GSN accessible to the general public through museum displays. By bringing live research-quality seismic data over the Internet and broadcasting it in museums, IRIS provides visitors with evidence that Earth's surface is in motion. Accompanying handouts and classroom exercises provide the visitor with follow-up educational materials. Currently, the IRIS Education and Outreach Program has museum exhibits at the American Museum of Natural History (NY), the Carnegie Museum of Natural History (PA), the New Mexico Museum of Natural History (NM), and an exhibit on tour with the Franklin Institute as part of their "Powers of Nature" exhibit. Together, these exhibits reach approximately 9 million visitors each year.

The **Thomas Edison Paper Project**, which NSF supported in the 1980s and early 1990s, has pursued the development of extensive materials accessible through the web. The Edison site now has more than a million pages on-line (http://edison.rutgers.edu/). NSF also continues to support the editing, annotating, and publishing of the ***Collected Papers of Albert Einstein***, of which Volume 8 was published in January 2002. The other large-scale, long-running

infrastructure project supported by NSF is the publication of the **letters of Charles Darwin**. In 2001 the project released Volume 12 of the letters, covering 1864.

NSF **Informal Science Education (ISE)** programs are directed at improving science, mathematics, and technical skills for citizens of all ages by addressing how families learn in informal settings and by involving parents as participants in children's science and math education. Projects targeting early childhood learners also demonstrate achievement of this indicator. ZOOM, a WGBH Educational Foundation media project and BUSYTOWN, an Oregon Museum of Science and Industry museum project, are examples of early childhood projects in science and mathematics programs supported by NSF.

National Virtual Observatory: FY 2001 saw the beginning of coordinated efforts to realize the National Virtual Observatory (NVO). This project, which received a strong recommendation from the recent National Academy of Sciences Decadal Survey, will federate astronomical data sets and establish them as a common resource for both researchers and the public. The project will focus not only on the archives, but also on establishing the protocols, standards, and tools that will permit the large astronomical datasets of the future to be fully utilized. Coordinated efforts are also underway at collaborating institutions to develop archives, visualization tools, and related resources. The first concept was developed with the help of an NSF Small Grant for Exploratory Research (SGER) award. NASA and NSF will be cooperating in this activity.

Area of Emphasis 1: Investments in K-12 systemic activities

The report ***Academic Excellence for Urban Students: Their Accomplishments in Science and Mathematics*** (Kim, 2001), an evaluative study of 22 of the Urban Systemic Initiative districts funded between 1994-1999, indicated that the urban program has been a catalyst for large-scale systemic change directed towards improving the science and mathematics achievement of all students. Further, the report presented evidence that the greatest gains were in districts that had participated in the Urban Systemic Initiative (USI) program for the longest period of time. Assessment results showed that USI students made gains in science and mathematics achievement, while reducing achievement gaps among racial/ethnic groups. Moreover, students in these districts substantially improved their enrollment rates in advanced science and mathematics courses. Additionally underrepresented minority students made even greater gains than their peers during the same period, resulting in reduced enrollment disparities in advanced courses. The study provides credible evidence that the implementation of a standards-based curriculum and instruction, aligned assessment practices, and appropriate professional development are key to an increase in student achievement. In addition, the results show that the convergence of resources, a strong leadership structure, and effective partners were also critical to the improvement in student performance. The study also concludes that it takes 7-10 years to bring about substantial improvement in systemic reform that may lead to the gains cited in the report.

The **Statewide Systemic Initiatives (SSI) Program** created “extraordinary activity in terms of very large statewide professional development efforts” and statewide curricular standards focused on more ambitious teaching and learning for children. In particular, there is evidence that infrastructures were created in state-level organizations to support this teaching and learning as well. The presence of such an infrastructure increases the likelihood that gains in student achievement will continue.

Area of Emphasis 2: Investments in enhancing instructional workforce (Centers for Learning and Teaching; Graduate Teaching Fellows in K-12 (GK-12) Education).

The **Centers for Learning and Teaching (CLT) Program** contributes in a significant way to the NSF's "enhancing instructional workforce" emphasis area. These centers offer a new approach to teacher education that responds to needs for increasing the ability of practicing teachers to deliver standards-based instruction; rebuilding and diversifying the national infrastructure for science, mathematics, and technology education; facilitating workforce induction/retention during initial years of service; and strengthening linkages between pre-/in-service teacher education. These large-scale projects are closely linked to K-12 school districts and required to build on shared expertise of local education agencies, institutions of higher education, and the informal science community. They link K-12, higher education, and/or informal science education performers to provide a systemic, K-graduate school approach for educating the instructional workforce in an environment of research and practice.

Two prototype centers were funded in FY 2000 and five additional full centers were funded in FY 2001. In addition, six Developmental grants were funded to build related institutional infrastructures.

The **NSF Graduate Teaching Fellows in K-12 Education Program** places graduate and advanced undergraduate students in K-12 schools to serve as science and mathematics content resources for teachers. The program supports the fellowships and appropriate training necessary for these fellows to enter the schools, but it is *not* a teacher preparation program. The primary objective of the program is to provide fellowships to highly qualified graduate and advanced undergraduate students in science, mathematics, and engineering and technology disciplines to achieve advanced degrees, *and* to contribute toward the improvement of the nation's schools, while introducing K-12 students and teachers to active researchers. This is part of a comprehensive approach to workforce development that reaches from grade school through graduate school. The expected outcomes of this initiative are: 1) improved communication and instructional skills for the Fellows; 2) professional development opportunities and content gain for K-12 teachers; 3) enriched learning by K-12 students; and 4) strengthened partnerships between institutions of higher education and local school districts. The GK-12 program seeks, in the words of one observer, to create "citizen scientists" for the 21st Century.

The AMANDA/IceCube project supported by the Graduate Teaching Fellows in K-12 Education Program (GK-12) is an exciting example of bringing scientific inquiry into the classroom. AMANDA (Antarctic Muon and Neutrino Detection Array) observatory located at the South Pole helps researchers track sub-atomic particles (neutrinos) as they pass by this array located 1500 meters below the polar ice cap. One of the teams supported by the GK-12 project integrates middle and high school education with the astrophysical research community involved with AMANDA. Graduate students, researchers, and teachers team up to develop a curriculum utilizing information generated by AMANDA. Through the "Astronomy in the Ice" course, teachers receive the astrophysical background they need to teach their students about AMANDA and related physical sciences. Throughout the year, graduate students serve as resource persons to schools while they establish communication networks with teachers and researchers. The GK-12 project couples education with the excitement of discovery and the understanding of science generated by the AMANDA/IceCube project.

Area of Emphasis 3: Investments in broadening participation (Tribal Colleges, Partnerships for Innovation).

The NSF initiative for *Tribal Colleges and Universities Program*[9] encourages Native Americans to pursue information technology and other science and technology fields of study, as well as increase the capacity of tribal colleges to offer relevant science and technology courses and enhance K-12 education in feeder school systems.

The project "Sustained Economic Growth of the **Oglala Lakota Nation** through Development of the Technological Infrastructure" is a multifaceted approach to developing the technological infrastructure of the institution and the reservation as a whole. Collaborations with several federal and state certified labs will provide the capacity to conduct research while strengthening curricula and developing new laboratory classes in several areas.

Programs are in place to foster gender-equity in the STEM disciplines such as the one at Arizona State University which involves guidance counselors who work with "**talented at-risk girls**" to improve self confidence and encourage them to enter the STEM fields. This program reached over 400 students at forty-eight schools including more than 100 Native Americans and 130 Mexican Americans.

The Rural Systemic Initiatives (RSI) Program has explicitly addressed the needs of **Native Americans** through the funding of several initiatives. An excellent example is the reconfiguration of the collaborative High Plains RSI into several individually funded RSI Tribal Colleges. By reallocating resources amongst the tribal colleges, the RSI has increased support to the rural systemic infrastructure serving Native American populations in the high plains. Another example would be the spin-off of the Navajo Nations RSI from the Utah-Colorado-Arizona-New Mexico (UCAN) RSI.

Two workshops brought together **Native experts** on sea-ice conditions that have affected whale hunting in the Arctic and scientists with their instrumental data, anthropological records, and sea-ice models. The symposia revealed a wealth of knowledge from both the scientific approach and Traditional Ecological Knowledge (TEK) that, when utilized together, enhance understanding of the impacts of environmental change on subsistence and cultural hunting practices.

NSF continuous its efforts to broaden community and public access to the benefits of scientific research. Several activities supported in 2001 were aimed directly at documenting **traditional indigenous knowledge**, cultural heritage, craft and subsistence practices for its sharing with and modern use by polar residents. Scientific knowledge collected by researchers and shared with communities increases awareness of modern economic, occupational, and social challenges, advances the ability to support public and educational initiatives, and improves potential responses in case of natural catastrophes and/or social losses.

[9] http://www.nsf.gov/pubs/2002/nsf02072/nsf02072.pdf, http://www.nsf.gov/od/lpa/news/press/00/pr0084.htm

NSF statistics show that large fractions of the students involved in the Engineering Research Centers (ERC) for FY 2000 were female and **underrepresented minorities** (URM). The 600 pre-college students included 48% female and 36% URM students; the 4000 undergraduate students included 29% female and 12% URM students; the 2200 graduate students included 22% female and 5% URM students; and the 344 Research Experiences for Undergraduate (REU) students included 39% female and 35% URM students.

With support from two NSF awards, researchers are addressing retention and participation of **traditionally underrepresented groups** in computing. Developing a framework involving undergraduate and graduate students in research, they have created laboratories to support research in neuro-fuzzy systems, parallel and distributed systems, signal processing and communication systems, software engineering, and theoretical applications. Students involved in this study include 73 graduate students (12 Ph.D. students); 102 undergraduate students; 136 students from underrepresented groups (38 female). To date 61 students graduated with BS; 38 students graduated with MS; two students graduated with a Ph.D. and 31 undergraduate students continued to graduate school. The distribution of publications, talks, and awards over the five years is as follows: over 150 research publications; over 100 research publications (journal and conferences) with students as co-authors; 23 publications and talks on the Affinity model; 66 student presentations at student conferences; 25 student awards and recognition.

The **Partnerships for Innovation (PFI) Program** focuses on connections between new knowledge created in the discovery process to learning and innovation. The goals of the program are: (1) to stimulate the transformation of knowledge created by the national research and education enterprise into innovations that create new wealth, build strong local, regional and national economies and improve the national well-being; (2) to broaden the participation of all types of academic institutions and all citizens in NSF activities to more fully meet the broad workforce needs of the national innovation enterprise; and (3) to create the enabling infrastructure necessary to foster and sustain innovation in the long term.

The $14 million in grants awarded in FY 2000 have been supplemented with over $7 million for 12 new grants[10] in FY 2001 to cover projects in 11 states involving more than 150 partner organizations. The lead institutions are selected to act as catalysts in helping their surrounding communities transform research-based knowledge into innovations that create opportunities for new wealth and a broader economic base that benefit communities and the nation at large. Examples of innovation that the grants are meant to foster might involve development of advanced new technologies to boost local economic growth. A university may serve as the research base, then incorporate its results into the corporate arena through knowledge and technology transfer. Corporate partners may develop the industrial processes for the innovation or product. Local governments or other non-profit activities may become a third leg in the partnership process by creating the climate for new businesses or funding the marketing of the product or innovation. Concurrently, a science and engineering workforce focused on innovation is created.

[10] http://www.nsf.gov/od/lpa/news/press/01/pr0188.htm#attachment

Area of Emphasis 4: Investments in addressing near-term workforce needs (Advanced Technological Education).

Advanced Technological Education (ATE) Centers of Excellence focus on systemic approaches to technician education, usually within a specific discipline. ATE Articulation Partnerships bring two-year colleges and four-year colleges and universities together to enhance two-year college programs for prospective K-12 teachers and for students who continue their education in four-year degree programs in science, mathematics, engineering, or technology. Fifteen Centers were active during FY 2001. In FY 2001 the ATE program supported 65 new projects and over 140 projects that were begun in previous years remained active. Cooperative efforts among ATE participants assure that the programs have a national impact. For example, the extensive collaborations of ATE projects with private industry have resulted in "skill standards" for technicians in particular fields and have enabled projects to develop real-world, workplace relevant educational materials and programs. In FY 2001 the program introduced two new emphases: (1) regional centers for information technology or manufacturing education to strengthen the workforce in the areas critical to the US economy and (2) "articulation partnerships" to facilitate the transition from two-year to four-year colleges for students preparing for technology careers or to become K-12 teachers.

The **Northwest Center for Emerging Technologies**, an ATE Center of Excellence at Bellevue Community College (Bellevue, Washington) is developing and refining industry-validated skill standards and associated curricula for information technology. The center's strategic partners include Microsoft, Boeing, and CompTIA (the Computing Technology Industry Association). In 1999–2000, those skill standards influenced or informed the education of approximately 78,000 students nationwide. In the same period, over 500 students took classes using courseware that the center developed in partnership with Dryden Online, and the center sold or licensed over 1,000 copies of its internally developed curricular products, which were used in the instruction of over 50,000 students. Microsoft recently produced a video profiling how the center stays on the cutting edge of information technology (IT) education.

The goal of "**Digital Arts and Sciences**" at the University of Florida is to train students to acquire a hybrid-knowledge of computer engineering and the arts, enabling them to understand the formalism of visualization and the practicality of human communications that deal with aesthetic interpretation. This enables students to work effectively in production-oriented teams focused on education, interactive games, scientific and engineering visualization, software engineering, and video production. Research is integrated in an Aesthetic Computing course and a series of Digital World Production Studio courses to the curriculum. Fine arts as well as computer science and engineering students will take these courses. "Aesthetic Computing" uses genres and styles in fine art as metaphors for formal and diagrammatically rendered model structures commonly found in computing, including automata, data flow graphs, data models, and the comprehensive Unified Modeling Language (UML). This work involves areas generally regarded outside the sphere of computer science, including semiotics, linguistics, analogy, metaphor, and the arts.

PERFORMANCE GOAL III-1b: Over 80 percent of schools participating in systemic initiative programs will (1) implement a standards-based curriculum in science and mathematics; (2) further professional development of the instructional workforce; and (3) improve student achievement on a selected battery of tests, after three years of NSF support.

✗ Goal Not Achieved

NSF manages a portfolio of programs that encourages and facilitates coordinated approaches to systemic, standards-based reform of science, mathematics, and technology (SMET) education. Systemic reform relies on partnerships to identify needs, articulate visions, and develop goals, strategies, and activities for improvement of targeted areas. Although each systemic initiative is unique in its approach, all must begin as a collaborative effort among individuals and organizations that are committed to requiring high expectations for all students through challenging educational opportunities. Systemic initiatives cultivate coordination within cities, states, rural areas, school systems, and other organizations involved with education.

RESULTS: We did not achieve this goal in FY 2001. The curriculum, instructional workforce, and improved achievement in science components of the goal were successful. However, less than 80% of schools met the goal of improved student achievement in mathematics. Forty-seven Systemic Initiative projects implemented mathematics and science standards-based curriculum in 89% of the participating schools and provided professional development for more than 226,900 teachers. The Systemic Initiative projects reported improved student achievement in math in 74% of the 6,255 schools and improved student performance in science in 80% of the 4,082 schools using the same assessments for the last 3 years.

FY 1999 Result: In 1999, 46 NSF-sponsored projects implemented mathematics and science standards-based curricula in over 81% of participating schools, and provided professional development for more than 156,000 teachers. All participating educational systems demonstrated some level of improvement in student achievement in mathematics and science.

FY 2000 Result: In 2000, 47 Systemic Initiative projects implemented mathematics and science standards in over 80% of the participating schools and provided professional development for more than 214,792 teachers. The Systemic Initiative projects reported improved student achievement in math in 81% of the 4,187 schools and improved student performance in science in 86% of the 2,474 schools using the same assessments for the last 3 years.

WHY WE DID NOT ACHIEVE THIS GOAL: No single factor has been identified that explains the drop in performance on student achievement relative to FY 2000 and FY 1999. Fluctuations in performance from year to year are expected, since there are differences in which schools are included within projects, and projects are able to use their own criteria for what constitutes an increase in student achievement. Review of performance data by NSF indicated that the goal for student achievement was not met for mathematics at some sites because, during the year, they adopted a more rigorous definition of increased student achievement.

STEPS WE WILL TAKE IN FY 2002 TO ACHIEVE THIS GOAL: In FY 2002, appropriate technical assistance will be provided to schools not meeting the goal.

IMPLICATIONS FOR THE FY 2002 PERFORMANCE PLAN: This goal will be maintained in FY 2002.

Performance Goal III-1c: Through systemic initiatives and related teacher enhancement programs, NSF will provide intensive professional development experiences for at least 65,000 pre-college teachers.

✓ Goal Achieved

Teacher professional development is a core strategy used by EHR-supported projects to promote reform. For example, in the Saint Louis Systemic Initiative schools, more than 75% (1,239 of 1,600) of the science and mathematics teachers received intensive professional development during the 1999-2000 school year.

RESULTS: In school year 1999-2000, EHR awards provided intensive professional development (60 hours or more) to a total of 79,000 teachers, exceeding substantially the GPRA goal of 65,000.

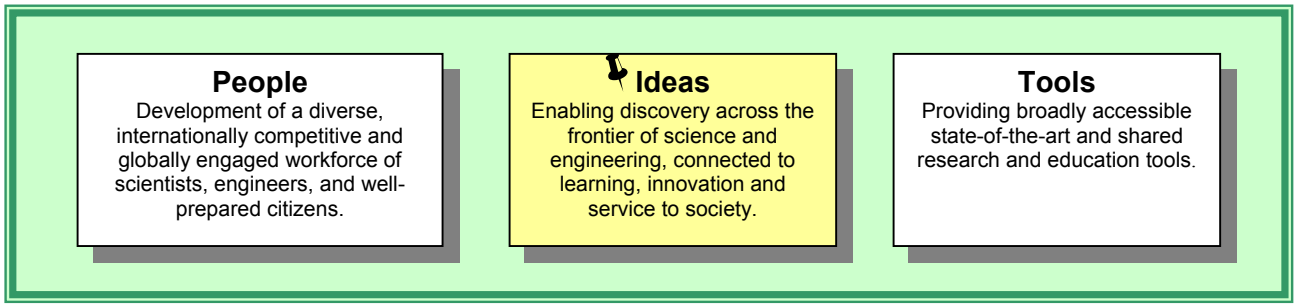
TEACHER PROFESSIONAL DEVELOPMENT				
	FY 1999	**FY 2000**	**FY 2001**	**FY 2002**
Goal	>65,000	>65,000	>65,000	N/A
Actual Number of Teachers	82,400	89,700	✓**79,000**[11]	

IMPLICATIONS FOR THE FY 2002 PERFORMANCE PLAN: This performance goal is not part of our FY 2002 Performance Plan. For FY 2002 NSF has reapportioned a substantial amount of the funds for the Systemic Initiatives to support the new Presidential Math and Science Partnership (MSP) activity. No new competitions or awards are anticipated under the Systemic programs. A goal related to the MSP has been included in the FY 2003 GPRA Performance Plan.

[11] The auditing firm of PricewaterhouseCoopers LLP (PwC) reviewed the data collection, maintenance, processing, and reporting procedures used to calculate results for this goal. They concluded that the procedures related to this goal were sufficient and adequate and yielded valid results. We provide the Executive Summary of their entire report, as well as a table listing their conclusions as to whether the processes we used for selected goals were verifiable and the results valid, in Appendix IV.

NSF OUTCOME GOALS

B. IDEAS



PERFORMANCE OUTCOME GOAL III-2: Enabling "discovery across the frontier of science and engineering, connected to learning, innovation, and service to society."

✓ Goal Achieved

NSF invests in ideas to provide a deep and broad fundamental science and engineering knowledge base. Investments in ideas support cutting-edge research that yields new and important discoveries and promote the development of new knowledge and techniques within and across traditional boundaries. The results of NSF-funded research and education projects provide a rich foundation for broad and useful applications of knowledge and the development of new technologies. Support in this area also promotes the education and training of the next generation of scientists and engineers by providing them with an opportunity to participate in discovery-oriented projects.

This is a new goal in FY 2001. Our performance is successful when, *in the aggregate*, results reported in the period demonstrate significant achievement for one or more of the following indicators:

- A robust and growing fundamental knowledge base that enhances progress in all science and engineering areas including the science of learning;
- Discoveries that advance the frontiers of science, engineering, and technology;
- Partnerships connecting discovery to innovation, learning, and societal advancement;
- Research and education processes that are synergistic.

RESULT: External experts provided examples of significant achievement in reports they developed during FY 2001 reporting. A sample of these is provided for each of the performance indicators and areas of emphasis for this goal.

IMPLICATIONS FOR THE FY 2002 PERFORMANCE PLAN: This goal will be continued in FY 2002. The performance indicators related to the Ideas goal have been expanded and modified to appropriately reflect the breadth of NSF activities (see Section X. for details).

INDICATOR 1: A robust and growing fundamental knowledge base that enhances progress in all science and engineering areas including the science of learning.

RESULT: ***Demonstrated significant achievement. Examples follow.***

One study that has captured significant scientific attention, as well as public interest, is the confirmation of viable microorganisms throughout the 4-km long ice column overlying **Lake Vostok**, **Antarctica**. This has implications for the presence of life in the lake itself. NSF supports a diversity of ecological investigations including Arctic bird adaptations, arctic tree growth and needle retention, establishing the metabolic rates of cold-adapted organisms, feedbacks between vegetation and climate change, and the phylogenetic composition of polar bacteria.

The 1987 Whittier Narrows earthquake revealed the need to improve understanding of the **impact of major natural disasters on the business sector**. Most of the existing research had focused on the economic impacts of disasters on households and families. The NSF-supported principal investigators were able to carry out a large-scale survey of businesses in Memphis/Shelby County, TN on business owners' perception of earthquake hazard, on their judgment of vulnerability to and effects of lifeline disruptions, and on their preparedness measures. Similar data was collected from the Northridge earthquake. Another NSF grant extended such studies to Santa Cruz County, CA and Dade County, FL. Overall, these studies have produced data on nearly 5,000 businesses of all sizes and types, comprising the largest database on business disaster readiness and effects in the world.

Advanced techniques have been developed for the communications, coordination, and vision of autonomous **multi-robot systems**. This allows robots to coordinate with each other in varying environments. When obstacles are presented in their path, the multi-robot systems can rearrange themselves to navigate around the object and then return to their original formation. For example, three small robots can coordinate themselves to sense, coordinate, and move a large object that could not be moved by a single robot.

What are the **predictors of children's learning interests** and how does parental involvement influence learning? Findings indicate specific parental traits that influence children's learning: Most importantly, children who develop focused encyclopedic play interests tend to have parents that value family discussions. Why does the value of family discussions predict children's interests? Children cannot easily learn about some domains without adult help; they need parents to talk with them about the domain, to read them relevant books, to participate in their play, and to provide them with relevant resources (toys, models, etc). Preschoolers cannot acquire this kind of knowledge on their own. The impact of **adult investment in child learning** is not insignificant: Children who develop focused encyclopedic play interests are more likely to be boys (by a factor of 5) and to demonstrate higher cognitive skills (particularly verbal).

An NSF-supported project has developed a process for the conversion of silicon carbide (SiC) to crystalline diamond at ambient pressure. This has direct application to the surface science of microelectromechanical systems (**MEMS**). The entire technological field of MEMS represents an area that is gaining momentum with the commercialization of these devices in applications in communications, transportation and aerospace. An article describing this work was published in *Nature* and received substantial attention from the news media.

A suite of investigations has examined the stability of the **West Antarctic Ice Sheet (WAIS)**, a potential contributor to rising sea levels. Results from glaciological modeling and glacial geologic research have highlighted a rapid retreat of the WAIS grounding line in the Ross Sea since the end the last glacial stage. Glacial geologists have developed a history of grounding line retreat for the WAIS. Results concerning the retreat of the WAIS have been of widespread interest, particularly for those who are studying past and present changes in sea level, ocean circulation, and atmospheric circulation.

Predicting the **properties of materials** from first principles (i.e. from the behavior of their atoms and molecules) is an important and challenging field. The challenge comes from the range of scales required - from electrons to clusters large enough to be seen. To span this range, researchers supported by NSF have developed numerical algorithms and a software infrastructure to implement hierarchical and adaptive methods to concentrate the solution on areas of greatest interest. The algorithms include techniques that improved previous techniques by 100-fold in terms of computer time and memory. The software infrastructure included the well-known Kernel Lattice Parallelism (KeLP) system, which manages communications among the memory hierarchies of parallel computers. KeLP is a framework for implementing portable scientific applications on distributed memory parallel computers. It is intended for applications with special needs, in particular, that adapt to data-dependent or hardware dependent conditions at run time. KeLP is currently used in full-scale applications including subsurface modeling, turbulence studies, and first principles simulation of real materials. In addition to materials design, KeLP has been applied to a wide range of partial differential equation solutions.

Neutron stars are born in supernova explosions when approximately one solar mass of burnt nuclear matter in the core collapses from about the size of the Earth to the size of an average city. The collapse of matter into this dense core can leave the **newborn neutron star** spinning extremely rapidly, some 1,000 revolutions per second. NSF-supported researchers have carried out the most detailed computational modeling ever done of the stability of these stars. In addition to surprising new insights into neutron stars, these simulations are yielding a clear “signature” to search for as the new Laser Interferometer Gravitational-Wave Observatory (LIGO) tries to detect gravity waves directly for the first time.

INDICATOR 2: Discoveries that advance the frontiers of science, engineering and technology.

RESULT: ***Demonstrated significant achievement. Examples follow.***

Researchers have, through the use of mathematical modeling, devised a simple and inexpensive method for the prevention of **Chagas disease**. A model predicted how four populations-bugs, chickens, dogs and people-interact with the protozoan parasite *Trypanosoma cruzi* each season in an individual household. The model allowed the researchers to determine that the practice of keeping chickens and dogs inside the house increased the population of blood-feeding bugs called triatomines, also known as the “kissing bug,” which in turn increase the parasite population that causes Chagas disease. By excluding infected animals from sleeping areas and spraying insecticides on a predetermined schedule, the people could virtually eliminate transmission of the parasite.

Cloning clock genes: In circadian biology, largely supported and fostered by NSF, “clock” genes have been cloned from several species, and the mechanisms by which circadian rhythms are generated are now being defined. In 1998 a Science magazine cited this research area as one in which major advances were made, and this research has now risen to the public consciousness. These areas, largely initiated by and nurtured by NSF, have become incorporated into the common knowledge base of undergraduate biology and ultimately many of the important advances are incorporated into the public consciousness.

The Arctic Oscillation and global change: The Arctic Oscillation, an annular mode of atmospheric circulation, has been linked in recent years to a variety of issues in the detection and diagnosis of global change. NSF-supported investigators have played leading roles in the study of this annular mode, beginning with Wallace and Thompson's introduction of the term "Arctic Oscillation" (or "AO") in the late 1990s. The AO is strongest in the Atlantic sector of the Northern Hemisphere and has direct effects on the climate of Eurasia, eastern North America, and the Arctic. A large portion of decadal climate variability, including large-scale temperature and precipitation anomalies in the Northern Hemisphere during the 1980s and 1990s, is associated with the AO. There is evidence of a similar mode in the Southern Hemisphere, where this mode appears to have played a role in recent trends in the atmospheric and sea ice conditions. It has been shown that the coherent vertical structure and phasing represents the strongest evidence to data of a dynamical coupling between the upper atmosphere and near-surface climate. There are tantalizing indications that stratospheric variations can precede surface variations, offering potential predictive possibilities for short-term climate variations, although the robustness and physical basis of this linkage require further investigation. In addition, there are suggestions that there may be a linkage between stratospheric chemistry (possibly including decreases of stratospheric ozone) and the troposphere via the stratospheric circulation.

Research groups supported by NSF pioneered the use of high precision measurements of the oxygen/nitrogen (O2/N2) ratio in air to study the biogeochemical cycles of carbon and oxygen. The ability to monitor these fluxes in real-time is clearly a critical asset in terms of developing the capability for managing a national or global carbon emission strategy. Using two independent techniques, mass spectrometry and interferometry, they have documented regional and global variations in O2/N2 and explored the use of this data to place constraints on the

fluxes of carbon dioxide (CO2) and oxygen between the atmosphere, ocean, and terrestrial biosphere. The combination of atmospheric O2/N2 and CO2 provides **a powerful tool to study the fate of fossil fuel.** This is true of CO2 because it allows discrimination between uptake via inorganic dissolution in the oceans (which does not release oxygen) and photosynthesis (which does release oxygen). The record to date has revealed significant interannual variability in the magnitude of the terrestrial biospheric sink for CO2. The ability to detect interannual variability in these fluxes is invaluable in terms of understanding the factors controlling them. For example, 1998 appears to be an anomalous year during which apparently all of the anthropogenically (man-made) emitted CO2 remained in the atmosphere and O2 fell abruptly. This suggests that more CO2 than usual was released by the land biosphere. This line of research has a significant impact on several fields of research, including climate, ecosystem studies, and oceanography.

Environmental factors in human health: The Center for Integrated Studies of the Human Dimensions of Global Change (CIS-HDGC) at Carnegie Mellon University has been exploring the ramifications of a broad range of interactions among human behavior, engineered systems, and natural processes through refinement, adaptation, and expansion of a highly sophisticated, integrated assessment model. In one application designed to better understand the role of environmental factors on human health, CIS-HDGC investigators developed and tested a model for assessing risks associated with *Cryptosporidium*, the water-borne parasite that sickened hundreds of thousands in the Milwaukee area during the early 1990s. The model integrates processes associated with engineering (water treatment technologies), ecology (land-use and land-cover patterns), biology, (proliferation of and testing for parasites), public health (surveillance and notification), and psychology (public perceptions and responses). One analysis using this model demonstrated that under typical conditions in the U.S., traditional responses to *Cryptosporidium* outbreaks calling for the boiling of drinking water are ineffective because most vulnerable people have been exposed before the problem is detected. Analyses designed to assess whether climate changes might increase threats to human populations demonstrated that changes in physical conditions were relatively unimportant as long as effective public health systems and procedures remained in place. As with related analyses of the risks associated with air pollution, the *Cryptosporidium* studies showed the importance of effectively incorporating social institutions into predictive models.

NSF has supported two major surveys of approximately 25,000 Internet users in late 1997 and late 1998 to examine **the sensitivity of Internet commerce to tax rates**. Tax sensitivity is high and is not falling despite the rapidly increasing number of new users because as new users gain experience, particularly young Internet users, their tax sensitivity appears to rise substantially. Internet commerce as a whole continues to be highly sensitive to tax rates and would fall significantly if existing sales taxes were enforced online. This research suggests that applying existing sales taxes to Internet commerce might reduce the number of online buyers by up to 24%. But the data also suggest that the potential sales tax revenue losses from continued exemption of Internet commerce would be quite modest over the next several years. So, taxing Internet commerce would not yield much government revenue and would substantially setback and slow the growth of e-commerce (http://gsbadg.uchicago.edu/).

An innovative proposal supported by NSF deals with the design of **palm size airplanes**, among the world's smallest, using flexible wings made of composite materials. The flight characteristics of these airplanes are similar to biological counterparts. The aircraft can be used in unmanned surveillance and reconnaissance missions.

An NSF award has supported groundbreaking research into the signal transduction pathway controlling responses to the hormone ethylene in plants. This research has used mutational and positional cloning approaches to identify genes that are involved in **ethylene signaling**. Ethylene signaling is now better understood than any other plant hormone signal transduction pathway. Responses to hormones such as ethylene affect plant growth and development, and their ability to adjust to adverse environmental conditions, and by extension to crop quality.

Classroom 2000: How does one substantially reduce the human input for creating and accessing large collections of multimedia, particularly multimedia created by capturing what occurs in an environment? The existing software system used as the starting point for this investigation is **Classroom 2000**, which is designed to capture what happens in classrooms, meetings, and offices. Classroom 2000 integrates and synchronizes multiple streams of captured text, images, handwritten annotations, audio, and video. In a sense, it automates note taking for a lecture or meeting. The research challenge is to make sense of this flood of captured data. The project explores how the output of Classroom 2000 can be automatically structured, segmented, indexed, and linked. Machine learning and statistical approaches to language are employed to understand the captured data. Techniques from computational perception are used to find structure in the captured data. An important component of this research is an experimental analysis of the software system being built. It is expected that this research will have a dramatic impact on how humans work and learn, as the developed technology will aid humans by capturing and making accessible what occurs in an environment.

Most physicists believe that general relativity ceases to provide a good description of the physical reality in the vicinity of the Big Bang. On general physical grounds it is clear that such a theory must incorporate effects not only of general relativity but also of quantum physics. NSF-supported researchers, attempting to unify general relativity and quantum physics, have found that at the tiniest scale conceivable today, called the Planck length (10^{-33} cm), the continuum picture of space breaks down and has to be replaced by a precise 'polymer-like geometry.' While at the laboratory scales (10^{-18} cm and above) this true geometry can be approximated by a continuum, the approximation fails miserably near the Planck scale. As the universe expands, its volume does not change continuously but only in discrete steps. Near the Big Bang one must abandon the use of differential equations on which most of physics is based and replace them by more fundamental difference equations describing the 'true' time-evolution. Once this is done, infinities disappear and regular physics is restored without any ad-hoc assumptions. While general relativity is an excellent approximation for today's universe, **space-time 'dissolves' near the Big Bang**. Einstein's deterministic, geometric universe has to be replaced by a specific, probabilistic universe built from polymer geometry.

INDICATOR 3: Partnerships connecting discovery to innovation, learning, and societal advancement.

RESULT: ***Demonstrated significant achievement. Examples follow.***

NSF's **Children's Research Initiative** (CRI) is providing five years of support for research centers that are developing new thrusts in the field of integrative developmental science. Individually, the centers represent leading edge research about children and media, developmental science, and the integration and dissemination of developmental science to inform both research and policy.

The *Research Center on Children and Media* is a collaboration of five research entities across four universities: Georgetown University, Northwestern University, University of Texas – Austin, and University of California-Los Angeles. The research activities of this center emphasize the types and impacts of emergent digital media on children; interactive media experiences on children's social and academic adjustment; how digital media impact learning; and influences of media on the developing brain.

The *North Carolina Child Development Research Collaborative (CDRC)* builds upon multidisciplinary activities across departments at the University of North Carolina-Chapel Hill, Duke University, University of North Carolina-Greensboro, and North Carolina State University. Investigators from diverse areas of developmental inquiry – health, nursing, social work, education, and developmental psychology – form the CDRC and have a common objective of developing an integrative model of developmental science. Their interdisciplinary approach to human development encompasses the main levels of analysis from the cultural and societal levels studied by anthropologists and sociologists to the neural and genetic levels studied by biologists and neuroscientists.

Development and use of a mixed-lubrication laboratory for **university-industry collaboration** and education has provided work experience for graduate students through partnerships with a major oil company, an automobile firm, a manufacturer, and a federal agency. In addition to enhancing the professional development of the Principal Investigator (PI), one post-doc, three graduate students and four undergraduates were involved in this project. There was interaction with NASA Marshall Space Flight Center, Mobil Technology Company, Ford Motor Company, Ilmor Engineering, Ltd and The Timken Company. These industrial partners provided the matching funds, enabling the PI and his students to leverage the NSF-supported research. Experiments were conducted in the university laboratory and at some of the industrial sites. A senior undergraduate/graduate course in tribology (the study of the effects of friction on moving machine parts) was developed and taught several times. Four industry experts were invited to give guest lectures to the class. The NSF funds were used as seed monies to stimulate the university/industry collaborations. Several students designed and built apparatus and computer programs that are now used at some of the industrial laboratories. The research collaborations led to links between theory and practice on how to best balance calculation accuracy and application practicality. Eleven conference and journal papers produced reflect this concept. The benefit of the award goes beyond the project period, since the PI still interacts with some of the industrial partners and is creating relations with new partners. Some of these new relations reflect ideas that were "seeded" during the NSF-funded project but came to fruition after it was completed.

In Antarctica, a recently recovered ice core from Siple Dome reveals a record of **rapid climate change** that appears to be correlated strongly with northern hemisphere changes. These data strongly suggest global links in the climate system. These data are also crucial for assessments of the state of the climate system, such as the recent Intergovernmental Panel on Climate Change (IPCC) 2001 Report, that provide information for policy-makers.

Icing models for aircraft: An NSF-supported Engineering Research Center at Mississippi State University working in collaboration with the Centers for Research Excellence in Science and Technology (CREST) project at Tennessee State University is engaged in the development, application, and evaluation of one-dimensional icing models with important implications for the safe operation of commercial aircraft.

NSF supports many atmospheric research programs that involve large numbers of partnerships – both among multi-disciplinary groups and among international researchers and institutions. The **U.S. Weather Research Program** (USWRP) is one such program. NSF, the National Oceanic and Atmospheric Administration (NOAA), the Federal Aviation Administration (FAA), and the Naval Research Laboratory (NRL) jointly support the USWRP. Its overarching objective is to conduct fundamental and applied research that will lead to improvements in various aspects of weather forecasting, such as hurricane landfall and quantitative precipitation prediction. The USWRP supports research in two categories--physical scientific research and identification of the societal needs for forecast information. The latter seeks to identify societal impacts of weather and weather information, determine the types of weather products that users require, and better understand how these products are or might be used. This, in turn, provides input and direction to the scope and focus of certain of the physical research studies.

A strong emphasis in the Experimental Program to Stimulate Competitive Research (EPSCoR) is the development of partnerships connecting discovery to innovation, learning, and societal advancement. A major concern of EPSCoR states is **economic development** and many EPSCoR projects produce results that are quickly transferred to industrial partners or result in new small businesses. One example involves the University of Alabama - Huntsville, where a team is developing an integrated research environment for intermeshed optoelectronics, thus allowing the study of systems in which optical and electronic elements are intermeshed in close physical proximity. Through the acquisition of a field emission scanning electron microscope the microfabrication facility is being expanded into a nanofabrication facility. The research and facilities supported by this project have resulted in over $1 million in fabrication contracts and $2 million in private cash donations for expansion of the cleanroom facility and purchase of additional equipment to expand nano- and microfabrication capabilities.

INDICATOR 4: Research and education processes that are synergistic.

RESULT: ***Demonstrated significant achievement. Examples follow.***

NSF supports a number of **Collaboratives to Integrate Research and Education (CIRE)**. These Collaboratives are designed to establish long-term research and education relationships between minority-serving institutions and NSF-supported facilities and centers by using both the human and practical resources of the facilities and centers to establish joint research programs and sponsor summer exchange programs. For example, the University of Puerto Rico at Humacao, and the Materials Research Science and Engineering Center (MRSEC) at the University of Pennsylvania are such a collaborative. A new Masters program in materials physics, the first graduate program at UPR-Humacao, has been developed through the collaboration. The annual University of Pennsylvania-UPR CIRE meeting was held in Puerto Rico in October 2000[12]. The meeting featured Alan MacDiarmid who gave an inspirational talk to over 400 undergraduate and high school students in Humacao. This was the first meeting MacDiarmid attended after he was recognized with the 2000 Nobel Prize in Chemistry earlier that month.

In 2001 NSF offered its third **Biology Training Course in Antarctica**. This past year an international graduate-level training course entitled "Integrative Biology and Adaptation of Antarctic Marine Organisms" was offered. Taught in Antarctica for one month during the austral summer, the participants included 22 individuals from six countries (18 graduate students and 4 postdoctoral researchers). The goals for the course were to introduce students to the diversity of organisms in Antarctica, to study the unique aspects of biology that permit life in such an extreme environment, and to give students firsthand experience in dealing with the unique problems inherent to Antarctic field sampling. The research emphasis of the course was on experimental Antarctic biology, allowing a number of aspects of evolution, physiology and ecology to be considered. These included investigations on bacteria, algae, invertebrates and fish that addressed molecular phylogeny, ultraviolet radiation effects, energy metabolism and biochemical adaptations to cold temperature. The course attracted an extremely competitive group of young scientists, introduced new researchers to Antarctica, and provided participants the opportunity to use the most modern research methods to study mechanisms that are unique to polar biology. The course also fostered collaborations between participants that will further influence their future research activities.

Research Experiences for Undergraduates (REU) Sites: This program introduces undergraduate students to meaningful science and engineering research, and in many cases, motivates them to continue studies for an advanced degree in the science and engineering disciplines. A hallmark of the REU program is diversity, not only in terms of the participating students, but also in the geographic locations, participating institutions, and available research areas. REU sites are located across the country. At all REU sites participating students choose research projects from a spectrum of both traditional and interdisciplinary topics. Some activities allow students to participate in international research collaborations. For example:

- The Division of Chemistry (CHE) has one of the largest investments in REU sites in the National Science Foundation. Support is provided for 64 sites in 32 states where more than

[12] http://www.lrsm.upenn.edu/lrsm/outr.html#CIRE

600 students conduct research each summer. Half the participants are female, and 23% are from underrepresented ethnic or racial groups.

- The REU sites supported in the Division of Astronomical Sciences play a crucial role in providing a science and technology workforce that reflects America's diversity. For example, of the 125 undergraduates supported in FY 2001, fully 50% of them were women and 15% were from members of underrepresented minority groups.
- The Division of Mathematical Sciences supported 243 undergraduates on research awards and an additional 296 undergraduates at 29 Research Experiences for Undergraduates (REU) sites.
- The Division of Physics supported 55 REU sites in 2001, providing undergraduate research opportunities for approximately 700 students. Eight of the physics REU sites also include Research Experiences for Teachers (RET) programs to bring high school teachers into the research experience.
- The Division of Materials Research supported the research efforts of well over 1,000 undergraduates in FY 2001, including 760 at REU Sites, Materials Research Science and Engineering Centers (MRSECs) and other national facilities, and several hundred more through individual-investigator awards. About 350 students participated in summer research experiences at 36 locations established through the annual NSF-wide REU site competition. In addition, 23 MRSECs supported by DMR in FY 2001 incorporated REU Sites as an integral part of the MRSEC efforts; about 380 students participated. DMR user facilities including the National High Magnetic Field Laboratory and the Synchrotron Radiation Center also supported REU Sites involving 30 students[13].
- The Cross-Directorate Activities Program (CDA) in the Directorate for Social and Behavioral Sciences supported 24 REU sites in FY 2001. Forty percent of the Principal Investigators for these sites are female and 13% are underrepresented minorities. Almost 50% of the nearly 200 students participating in these sites are underrepresented minorities and two-thirds are female.
- One additional example comes from the **Oklahoma Weather Center (OWC)** REU activity. It is bringing 30 undergraduate students, over a three-year period, to Norman, Oklahoma to participate in the OWC program. Each student: 1) was matched with an atmospheric scientist based upon his/her interest and ability to conduct research; 2) attended atmospheric science lectures; 3) participated in workshops on topics such as technical writing, numerical modeling, meteorological tools, graduate school preparation; 4) participated in field trips to regional sites; 5) tried various research methods, 6) collected and analyzed data; and 7) presented his or her research results in an formal presentation and a written paper. The NSF REU program was leveraged by incorporating students participating in similar programs sponsored by NSF's CIRE (Collaboratives for Integration of Research and Education) and the Department of Energy's ORISE (Oak Ridge Institute for Science and Education) programs.

[13] http://www.nsf.gov/mps/divisions/dmr/research/c_reusites.htm

Area of Emphasis 1: Appropriate balance of high risk, multidisciplinary or innovative research across all NSF programs.

Maintaining a diverse, balanced portfolio is an essential aspect of any investment strategy, and this holds true for investments we make in science and engineering research and education. We recognize that there is a significant probability of failure associated with high-risk research, that there is often a lack of experimental data or methodologies, little consensus on theory, information and/or approach. If successful, however, such high-risk research can result in a significant advance in a scientific or technological field. In addition to our regular grants, our Small Grants for Exploratory Research (SGER) are meant to encourage Program Officers to invest in new, innovative concepts and ideas and to support small-scale, high-risk exploratory work.

Our external reviewers assessed our investment portfolio for FY 1998, FY 1999 and FY 2000 with respect to this area. There were numerous comments on this area of emphasis, and the vast majority of these comments indicated that investments made by the Directorates contained an appropriate balance of high-risk, multidisciplinary or innovative activities. Some of our COVs felt, however, that NSF needed to support more high-risk activities. Some comments from our Advisory Committees and COVs:

- "In FY 2001, the Directorate funded $28.14 million in awards for the Network for Earthquake Engineering Simulation (NEES)—a high risk program to shift the emphasis of earthquake engineering research from physical testing to integrated experimentation, computation, theory, databases, and model-based simulation."

- "The Engineering Directorate invests heavily in high-risk research and education activities in Nanoscale Science and Engineering."

- "In addition to the single investigator grants, the directorate places a high priority on multidisciplinary work and on partnerships. Within MPS, the Office of Multidisciplinary Activities serves as a catalyst in emerging areas of research and education at disciplinary boundaries."

- "The balance of high-risk, multi-disciplinary or innovative research was cited as a particular success; the examples give ample evidence of success; the awards in the ITR program position CISE for continued success in this area of emphasis."

- "The OAC noted that the mix of research activities OPP sponsors cuts across the spectrum from high risk to high innovation. In supporting research that is considered on the "cutting-edge," OPP makes investments that require taking risks."

- "The COV generally felt there was a good balance to the portfolio but more high-risk projects should be considered …."

- "All projects, because of the nature of the program, systemic focus in extremely complex organizations that serve urban, diverse, low-socio-economic districts, are high-risk. In this area, balance of the portfolio is especially important."

- "Using data compiled by the Division for its various component programs, it is clear that funded proposals generally display a high degree of novelty and disciplinary impact with a medium (theory) to medium high (experimental) level of risk. There was no evidence of bias against proposals, which were of high risk, multidisciplinary, and innovative. There was appropriate evidence of bias against proposals that were not innovative. In two cases, one could interpret the unsuccessful outcome of the proposals as being due to an insufficient level of risk."

- "The division seems to have an appropriate balance of high risk and multidisciplinary projects."

Examples of high-risk, innovative, or multidisciplinary awards include support to:

- Determine whether electrical stimulation can control neural cell behavior as well as chemicals;
- Explore the use of nanotechnology techniques for DNA sequencing, based on a pioneering technology that combines the fields of nanotechnology, new fractionation science, and single-molecule molecular biology. This technology could become the basis for the development of a "biology laboratory on a chip."
- Develop novel experimental techniques that will make it easier to study chemical reactions at the atomic scale. The results will pave the way for the design of catalyst nanoparticles to enhance the performance of methanol fuel cells.
- Develop a multidisciplinary bioprocessing curriculum that integrates expertise from biochemistry, microbiology, chemistry, botany, and chemical engineering. This effort has led to a new multidisciplinary graduate training program in "technologies for a bio-based economy."
- Investigate the feasibility of creating sophisticated folded structures from metal and polymer sheets for applications requiring light but stiff structures;
- Work with automotive engine designers to cut down vibration and shake in combustion engines. Researchers are exploring an approach similar to that used in skyscrapers.
- Develop computational and statistical methods to evaluate comparative genetic map data;
- Test a novel expression vector system developed to directly rescue open reading frames (ORFs) from genomic DNA;
- Collect large amounts of expressed sequence information for floral structures across the angiosperms and gymnosperms, and use the information to determine which genes are required for floral organ development. This represents the first of a new kind of Virtual Center funded in FY 2001. Its focus is "evolutionary genomics".
- Determine the presence or absence of biological signatures in Antarctic meteorites;
- Use high-resolution satellite imagery to census Emperor penguin colonies;
- Develop new sampling and measurement methods and tools to explore under the Arctic Ocean ice cap in the Gakkel Ridge region;
- Develop autonomous underwater vehicles (AUVs) designed to explore and collect samples from underneath Arctic sea ice or Antarctic ice shelves;
- Study biology on surfaces. This is an example of research at the interface between the physical sciences of surfaces and the life sciences of biological organisms.
- Have a highly multidisciplinary team of scientists look at environmental catalysis and environmental interfacial characterization.

Area of Emphasis 2: Investments in three initiatives [Information Technology Research (ITR), Nanoscale Science and Engineering, Biocomplexity in the Environment (BE)].

Examples follow.

A number of multidisciplinary areas of research and education are identified as being of particular importance for their potential connections to use in service to society. These fit within the Foundation's broad emphasis areas of ITR, BE, and Nanoscale Science and Engineering. The amounts invested in FY 2001 are given in the following Table:

FY 2001 INITIATIVES (MILLIONS OF DOLLARS)	
Information Technology Research	$216.27
Nanoscale Science and Engineering	$149.68
Biocomplexity in the Environment	$54.88

Information Technology Research **(ITR):** We have been designated as lead agency for a multi-agency *Information Technology Research* initiative begun in FY 2000. In supporting research and education in the ITR area, we work in partnership with other agencies.

Advanced information technology has expanded the scope of science and engineering – from the subatomic level to the cosmos – by adding the computer as a third partner to the time-tested methods of theory and experimentation. This new, virtual mode of inquiry is where much of today's most important fundamental research is happening. Virtually every field of science and engineering now benefits from – and in many cases relies heavily on – the use of information technology (IT)

IT research and education has also fundamentally changed almost every sector of our **society and economy**. Economists, including Federal Reserve Bank chairman Alan Greenspan, agree that advances in IT have dramatically boosted productivity of the U.S. workforce. To quote Mr. Greenspan:

> "When historians look back at the latter half of the 1990s a decade or two hence, I suspect that they will conclude we are now living through a pivotal period in American economic history….It is the growing use of information technology throughout the economy that makes the current period unique[14]."

While development of commercial products is not the point of basic IT research, the field has recently yielded spectacular results. In the early 1990s, for example, students working under the direction of senior researchers at an NSF supercomputing center helped create Mosaic, the **web browser** that helped trigger a new era of electronic commerce. Other prior successes of NSF-funded IT research and education activities include the vast expansion and privatization of

[14] Speech to the Boston College Conference on the New Economy, March 6, 2000

Internet infrastructure in the mid-1990s, and projects that led to many of today's leading commercial web search engines such as Lycos, Google and Inktomi.

- **Intelligent radar sensors:** NSF supported an ITR award for the development and deployment of intelligent radar sensors for measuring key glaciological parameters. Radar instrumentation will consist of a synthetic aperture radar (SAR) that can operate in bistatic or monostatic mode. A tracked vehicle and an automated snowmobile will be used to test and demonstrate the utility of an intelligent radar in glaciological investigations. This project involves innovative research in intelligent systems, sounding radars and ice-sheet modeling. In addition it has a very strong public outreach and education program that includes near-real-time image broadcasts via the World Wide Web.

- NSF is supporting a project to make computers more proactive in their interactions with people. In **human interaction**, someone who waits for each command before making any communication attempt would be regarded as uncooperative and unhelpful. In order for a computer to bear its part of the burden in initiating interactions, it must first have much more real-time information about its user, and second, algorithms that select actions based on this information, in addition to user commands. The computer needs information about the user's current and past emotional, motivational and cognitive state, as well as the state of the task at hand. Research and education activities will include development of methods to sense user postures, movements, expressions and speech; fusion of this information to track user states; creating means for effective communication, human-centered action decisions, and a corpus of emotion- and action-labeled videotapes for use with computer learning; and finally, evaluation of computer pro-action on human behavior and response.

Nanoscale Science and Engineering **(NSE)** represents a new focused investment opportunity in FY 2001. Support for nanoscale research and education is motivated by the impressive potential for economic return and social benefit. The initiative will lead to potential breakthroughs in areas such as materials and manufacturing, nanoelectronics, healthcare, environment and energy, chemical and pharmaceutical industries, biotechnology and agriculture, computation and information technology, and national security.

Areas of emphasis include biosystems at the nanoscale, nanoscale structures and novel phenomena, device and system architecture, nanoscale processes in the environment, multi-scale and multi-phenomena modeling and simulation. NSF supports a wide range of research and education activities in this priority area, including approximately 15 nanotechnology research and education centers, which focus on electronics, biology, optoelectronics, advanced materials and engineering. Examples of collaborations with other agencies and private sector include: quantum computing with DARPA; Materials Research Science and Engineering Centers (MRSEC) with the Department of Defense (DOD); Semiconductor Industry Association and Engineering Research Centers (ERC); Grant Opportunities for Academic Liaisons with Industry (GOALI) awards (collaboration with private sector); and cofunding two new Nanoscale Science and Engineering Centers (NSEC) with the DOD.

- **Societal implications of nanotechnology:** On September 28-29, 2000, a workshop was held at NSF on “The Societal Implications of Nanoscience and Nanotechnology.” The aim was to: (1) survey current studies on the societal implications of nanotechnology (educational, technological, economic, medical, environmental, ethical, legal, etc.); (2) identify investigative and assessment methods for future studies of societal implications; and (3) propose a vision for accomplishing nanotechnology’s promise while minimizing

undesirable consequences. The extensive report of this workshop has been published both on the web and in book form and has also been distributed to all agencies and to the President's National Science and Technology Council. A second workshop was held December 3-4, 2001, to address how cognitive science can be integrated with nanotechnology, biotechnology and information technology to enhance human performance.

- **Manipulating Matter at the Nanoscale:** Manipulating matter on the nanometer scale is important for many electronic, chemical and biological advances. Available solid-state fabrication methods do not reproducibly achieve nanometer-scale dimensional control. However, an ion beam can be used to poke holes in thin films to produce structures that are used to manipulate nanoscale matter. The method can fabricate a molecular scale hole, or nanopore, in a thin insulating solid-state membrane. Nanopores localize molecular scale junctions and switches and act as masks to create other small structures. Nanopores also function as membrane channels in all living systems, where they are extremely sensitive electromechanical devices that regulate electric potential, ionic flow and molecular transport across cellular membranes. "Ion beam sculpting" has been used to fabricate a robust electronic detector capable of registering single DNA molecules in aqueous solution. Such detectors may find utility in extremely rapid sequencing of DNA for medical diagnostics of genetic diseases and rapid drug design for large populations.

Biocomplexity in the Environment **(BE)** became an area of focus in FY 1999, beginning with a special competition on the "Interrelationships between Microorganisms and Biological, Chemical, Geological, Physical, and Social Environments." In FY 2000, NSF sponsored a $50 million initiative – *Integrated Research to Understand and Model Complexity Among Biological, Physical, and Social Systems*. In FY 2001 and FY 2002 the Biocomplexity in the Environment competitions focused on Integrated Research and Education in Environmental Systems.

Understanding the dynamics of biological complexity and its role in environmental systems is critical to knowledge of living organisms and of the vital natural resources biological systems provide (e.g., food, fiber) and upon which humans depend. Advancing our understanding of the nature and role of biological complexity demands increased attention and new collaborations of scientists and engineers from a broad spectrum of fields – biology, physics, chemistry, geology, hydrology, statistics, engineering, computation, social sciences. Such collaborations can capitalize on powerful new emerging technologies – including genome sequencing, new computational algorithms and mathematical methods, sensors and monitoring devices, and remote sensing – that have greatly enhanced our ability to understand ecosystem complexity and dynamics.

- *Organohalide Pollutants***.** Organohalides pose serious threats to air and water quality. They are among the most widely used industrial chemicals, with applications in such familiar processes as dry cleaning and air conditioning. Of the top 25 organic contaminants found in ground water in U.S. urban cities, 17 are organohalides. Investigators and their collaborators from national laboratories and industry are studying ways to break down organohalides into less toxic substances. They hope to develop new techniques for detecting environmental organohalides, predicting and monitoring their rates of natural attenuation, and, wherever practical, decontaminating sites where organohalides are found.

Area of Emphasis 3: Investments in non-initiative fundamental research (Mathematical Sciences Research, Functional Genomics, Cognitive Neuroscience).

Examples follow.

Mathematical Sciences Research:

- **The Simplex algorithm:** Two NSF-supported investigators have solved a long-standing open question in mathematical programming, optimization, and theoretical computer science, proving that the Simplex Method for Linear Programming usually takes a polynomial number of steps. They developed a new algorithm-analysis framework, called smoothed analysis, which can help explain the success of many algorithms and heuristics that traditional algorithm-analysis frameworks, such as worse-case and average-case analysis, cannot. The simplex algorithm is a classic example of an algorithm known to perform well in practice yet it consumes exponential time in the worst case. It has been an active subject for mathematical and experimental studies for more than 50 years.

Functional Genomics:

- The research project, "The Role of Gamma Aminobutyric Acid (GABA) in Plant Growth and Productivity," awarded to Sun Dance Genetics, Durham, NC has added to understanding of the role of GABA in plant growth. Commercial application of formulations containing GABA is found throughout the world. Agriculture, horticulture, floriculture, and **turf grass** industries are now benefiting from a product that increases plant growth and productivity while reducing the amount of fertilizer needed for optimal plant productivity. The results of this NSF-supported research have established the efficacy of the company's formulations for increasing plant growth and productivity and reducing a plant's fertilizer requirements, and demonstrate their commercial utility. The company estimates the total U.S. market opportunity for such products to be approximately $3.0 billion per year.

- ***Arabidopsis thaliana*:** DNA sequence data is an essential tool but is not enough to tell us everything about how an organism develops and functions. Building on the large and growing store of information amassed in the international sequence databases, biologists are now able to tackle the next frontier in biology, functional genomics, which uses genome sequence information in combination with data from other biological research to study what genes do – that is, how patterns of sequence are related to patterns of function. Functional genomics offers unprecedented opportunity to understand living systems through use of large-scale, genome-derived information. NSF's first major program in functional genomics, the "2010 Project," began in FY 2001, and will continue through the year 2010. Its goal is to determine the functions of the 25,000 genes of the flowering plant, *Arabidopsis thaliana*.

- **How insects develop immunity to plant toxins:** *Bacillus thurnigiensis* (Bt) is a bacterium that produces toxins with insecticidal activities. One of the early success stories of genetic engineering of plants was the introduction of the gene encoding the toxin into agriculturally important crops, such as cotton. These plants produced their own pesticide thereby reducing the need for chemical pesticides. Unfortunately, insects can "learn" (evolve mechanisms) to escape this clever trap, and develop resistance to the toxin but the molecular basis for resistance was unknown. In 2001, two independent groups focusing on

the molecular mechanism of Bt toxin resistance in two plant pests produced important results that were reported in back-to-back papers that appeared in *Science*, August 2001 and were highlighted by a “news and views” report.

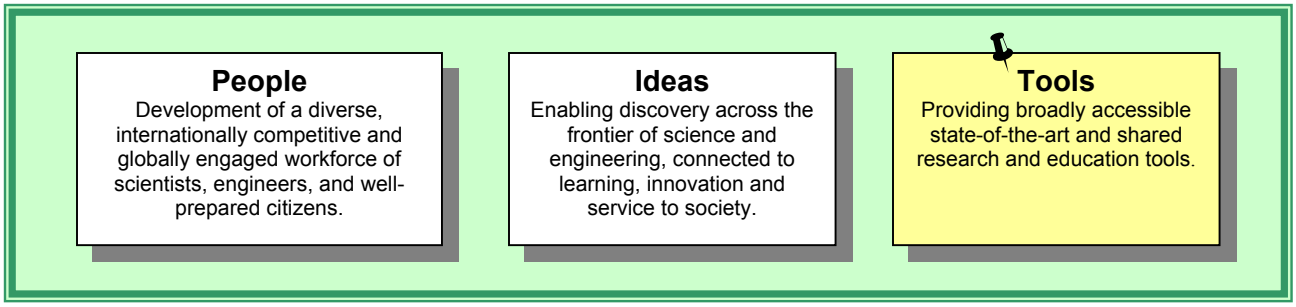
Cognitive neurosciences:

- **How bees learn:** Studies of the neuroanatomical basis of hormone-mediated behavioral development in the honeybee have shown that such bees learn olfactory associations as they emerge from the hive to forage for flower nectar. These studies are the first to use a social insect as a model system to assess the effects of a hormone on cognition, and provide a new perspective for understanding bee foraging behavior. They could also have substantial impact on agriculture. There has been a large response in the popular press to this work, with coverage from the New York Times, National Public Radio, the BBC and many other European news organizations.

- **Mapping brain function:** A conformal map of one region to another preserves angles between intersecting curves, a property that is especially valuable in the study of regions such as the visual cortex of the brain. Conformal geometry is being used to map brain function using conformal mapping algorithms and other geometric ideas. These efforts at brain mapping have been described in several widely-read accounts, such as an article in the August 2001 issue of *Scientific American*.

NSF OUTCOME GOALS

C. TOOLS



PERFORMANCE OUTCOME GOAL III-3: Providing "broadly accessible, state-of-the-art and shared research and education tools."

✓ Goal Achieved

NSF invests in tools to provide widely accessible, up-to-date science and engineering infrastructure. This strategic outcome supports the parts of NSF's mission directed at (1) programs to strengthen scientific and engineering research potential and (2) an information base on science and engineering appropriate for development of national and international policy.

As emerging research opportunities increasingly involve phenomena at or beyond the limits of our measurement capabilities, many research areas can only be studied and problems solved through the use of new generations of powerful tools. NSF investments provide state-of-the-art tools for research and education, such as instrumentation and equipment, multi-user facilities, digital libraries, research resources, accelerators, telescopes, research vessels and aircraft and earthquake simulators. In addition, resources support large surveys and databases as well as computation and computing infrastructures for all fields of science and engineering research and education. Support includes funding for construction, upgrade, operations, and maintenance of facilities, and for personnel to assist scientists and engineers in conducting research and education at the facilities.

This is a new goal. Our performance is successful when, *in the aggregate*, results reported in the period demonstrate significant achievement for one or more of the following indicators:

- Shared use platforms, facilities, instruments, and databases that enable discovery and enhance the productivity and effectiveness of the science and engineering workforce;
- Networking and connectivity that take full advantage of the Internet and make SMET information available to all citizens;
- Information and policy analyses that contribute to the effective use of science and engineering resources.

RESULT: Reports prepared by external experts during FY 2001 GPRA reporting provided assessments and retrospective examples of NSF-supported projects that document significant achievement. A sample of these is provided for each of the performance indicators and areas of emphasis for this goal.

There are very limited contributions and limited involvement of agency programs, other than Science Resources Statistics (SRS), in developing information and other materials fundamental to national policy debates.

IMPLICATIONS FOR THE FY 2002 PERFORMANCE PLAN: This goal will be continued in FY 2002. The performance indicators related to the Tools goal has been expanded and modified to appropriately reflect the breadth of NSF activities (see Section X. for details).

INDICATOR 1: Shared-use platforms, facilities, instruments, and databases that enable discovery and enhance the productivity and effectiveness of the science and engineering workforce.

RESULT: ***Demonstrated significant achievement. Examples follow.***

The **Incorporated Research Institutions for Seismology** (IRIS) seeks to image, at high-resolution, the structure and composition of the entire Earth. This image will form the basis for a new, physics-based description of the dynamics of the whole Earth. Moreover, using Internet technology, the data management program will make these state-of-the-art data available to anyone in the world, promoting a powerful synergy of research and education. The scale of the facility, like the scale of the problem, is large, encompassing a partnership of 96 institutions and hundreds of individual researchers and research projects.

The **national astronomy facilities,** consisting of the National Radio Astronomy Observatory, the National Optical Astronomy Observatory, the National Solar Observatory, the National Astronomy and Ionosphere Center and Gemini Observatories, provide access to a broad scientific community on the basis of scientific merit review. Each facility provides unique capabilities to over 2,400 scientists and their students of whom over half were pursuing their doctorates. The Atacama Large Millimeter Array (ALMA), which will bring aperture synthesis techniques to radio astronomy, is in the last year of design and development prior to project construction involving an equal U.S.-European partnership.

Materials Research Facilities: The major-shared facilities include the National High Magnetic Field Laboratory (NHMFL), the Center for High Resolution Neutron Scattering (CHRNS), the Cornell High Energy Synchrotron Source (CHESS), the Synchrotron Radiation Center (SRC), and the National Nanofabrication Users Network (NNUN). Each of these facilities operates to enhance the productivity and effectiveness of scientists and engineers in a wide range of disciplines. For example, the NHMFL is operated by a consortium composed of the University of Florida, Florida State University and Los Alamos National Laboratory and NHMFL and has established itself as the world's leading center for multidisciplinary research and education using high magnetic fields.

Polar Facilities: NSF manages and operates the three permanent U.S. stations in Antarctica (South Pole, McMurdo and Palmer). These stations provide the facilities for U.S. scientists, including those from other federal agencies, to conduct research in Antarctica in widely divergent disciplines. NSF also supports both permanent and seasonal stations in the Arctic. In the past two years the Summit Station (Greenland) has operated year-round to support winter observations with a particular emphasis on atmospheric chemistry.

Forecasting Lightning Strikes: A Lightning Mapping Array (LMA) has been developed and uses very accurate Global Positioning System (GPS) timing capabilities to measure the time of arrival of electrical discharges at a dense array of receivers to provide a very accurate three-dimensional map of the structure and evolution of cloud-to-ground (CG) and intra-cloud (IC) lightning. Because IC discharges typically occur about 15 minutes before the onset of CG strokes, the LMA provides added lead time for use in forecasting the onset of lightning strokes hitting the ground (one of the deadliest weather phenomena occurring today). It also provides a natural complement to weather radar, and together they offer the

promise for improvements in the accuracy and timeliness of short-term forecasts of severe convective weather.

Gemini and Laser Guide Stars: NSF serves as the executive agency for the Gemini Observatories, an international project with seven partner nations (the U.S., the United Kingdom, Canada, Australia, Chile, Brazil and Argentina). The Gemini Observatories consist of two 8-meter telescopes, one located in the southern hemisphere in Chile, and one located in the northern hemisphere in Hawaii. NSF provides 50% of the funding, enabling merit-based access to both telescopes for the U.S. national community. The project has also played a pivotal role in sodium laser tests sponsored by Gemini, the Cerro Tololo Inter-American Observatories, and the European Southern Observatory.

NSF is the major source of support for the **Panel Study of Income Dynamics (PSID)**, a survey of a nationally representative sample of U.S. individuals and the family units in which they reside and was initiated in 1968. The major objective of the panel is to provide shared-use databases, research platforms and educational tools on cyclical, intergenerational and life-course measures of economic and social behavior. The PSID's innovative design and long-term panel have been central to the fundamental understanding of key social science issues with substantial broad impacts on society: income, poverty and wealth; cyclical behavior of wages, labor supply and consumption; savings, wealth accumulation and transfers; demographic events; labor market behavior; and the effects of neighborhoods.

PSID data transformed research on poverty from a static view of poor and rich to a dynamic one in which families experience episodes of poverty or affluence. PSID results have been replicated and validated. The enormous usefulness of decades of data on the sample families has made the PSID one of the most widely used social science data sets in the world. The project currently delivers more than 10,000 customized data sets a year to researchers via its Internet Data Center. Since 1968, over 2,000 journal articles, books and chapters, dissertations and other works have been based on PSID data. More information on the PSID is available at http://www.isr.umich.edu/src/psid.

The NSF-funded **General Social Survey** (GSS) has been monitoring social change in the United States, examining sub-groups in society, and studying social processes since 1972. Over this period, 23 cross-sectional surveys of the U.S. adult household population have been completed, involving face-to-face interviews with approximately 41,000 respondents. Surveys document fundamental social change in areas such as uses of technology, social and cultural capital, neighborhoods and communities, social networks, and racial and gender attitudes. The GSS is widely used by the academic research community and scholars at research centers, foundations, and in government. For example, as of April 2000, there were 5,430 documented uses of the GSS data, including 2,676 journal articles, 1,201 books, 959 scholarly papers and 153 dissertations and theses. The GSS is used extensively in teaching, with GSS having been utilized in 226 textbooks and contained in course materials on 224 websites. The cumulative GSS data files are used in the Inter-University Consortium for Political and Social Research (ICPSR) Summer Program, which is annually attended by 150 scholars representing over 100 colleges in the United States and Canada.

The World Data Center for Paleoclimatology (WDCP) is housed at the National Oceanic and Atmospheric Administration's (NOAA) National Geophysical Data Center at Boulder, Colorado. Data sets include tree-rings, lake core records, ice core records, ocean sediment records and corals, developed in part by NSF-supported researchers.

INDICATOR 2: Networking and connectivity that take full advantage of the Internet and make science, mathematics, engineering and technology (SMET) information available to all citizens.

RESULT: ***Demonstrated significant achievement. Examples follow.***

The objective of the National Science, Mathematics, Engineering and Technology (SMET) Education **Digital Library** (NSDL) is to catalyze and support significant advances in the quality of SMET education at all levels by providing broad access to the rich collections of teaching and learning resources of the nation in a distributed, digital environment. The NSDL aims to create, organize and install high-quality education resources onto the Internet. The program may strongly affect K-12 and undergraduate educational by providing anytime, anywhere access to a rich array of authoritative and reliable interactive materials and environments. Some of the newly funded projects focus on gathering and organizing content in areas such as geosciences, life sciences, engineering and mathematics. Others will develop the processes to manage and coordinate that content in the library's core collections, and develop services for users and collection providers. The program continues ongoing efforts of the national, multi-agency Digital Libraries Initiative begun in 1994, which has involved NSF, the Defense Advanced Research Projects Agency, the National Aeronautics and Space Administration, and other federal agencies.

The **Performance Assessment Links in Science** (PALS) project has created an on-line web-based assessment resource for teachers and test developers. The teacher site includes science performance tasks, with information on which national science standards are addressed, its psychometric properties, scoring rubric, and examples of students' work. This rich resource is used by teachers nationally, including Chicago, Los Angeles, San Mateo (CA), and the Spring Independent School District (TX). PALS also is used in several NSF-supported Urban Systemic Initiative sites to help document program effectiveness through improved student achievement.

The Space Science Institute has developed the **Space Weather Center web site** as part of the National Space Weather Program (NSWP). The web page can be viewed at http://www.spacescience.org/. It serves as a central outlet for public information on space weather by providing a collection of resources of interest to educators, the media, and the general public. The web site includes introductory information on space weather, an image archive of the best images from space weather research programs, brief reports written by space weather researchers, links to current solar and space weather data, and links to downloadable curricula related to space weather. A new capability installed in the past year allows visitors to the web site to take a virtual tour of any of several space weather museum exhibits the Space Science Institute has developed.

In FY 2001 NSF awarded **high performance network connections** to 19 universities, a research museum, and two research institutes, bringing the total of institutions assisted through such grants to 221. Since 1995 the NSF High Performance Network Connections (HPNC) program has provided scientists and engineers better access to research facilities across the U.S., including those maintained by NSF through its Partnerships for Advanced Computational Infrastructure (PACI) program. The new awardees will join in connecting to a national grid of research networks that operate at speeds up to 2.4 billion bits per second.

Mathematics: Software available through the Internet has been developed for the solution of partial differential equations via numerical analysis or object-oriented code, for the teaching of finite element analysis, and for the solution of linear recurrence equations. In addition, the conservation law package (CLAWPACK) has been freely available on the Internet to researchers using multidimensional high-resolution finite-volume methods for solving hyperbolic partial differential equations. For example, the equations can simulate ultrasound propagation in human tissue, elastic waves in heterogeneous media, and gravitational waves of planetary bodies indicating applicability to biosciences, materials science and astronomy.

Through the **WEB100** project, universities, research centers, and some businesses today have connections capable of transmitting data at 100 megabits per second (Mbps) or higher. Research has shown, however, that users rarely see performance greater than 3 Mbps. New WEB100 software, developed jointly by the National Center for Atmospheric Research (NCAR), the Pittsburgh Supercomputing Center, and the National Center for Supercomputing Applications, with funding from NSF, will allow users to take full advantage of available network bandwidth without the help of a networking expert. WEB100 researchers traced the problem of poor performance to software that governs the Transmission Control Protocol (TCP). Networking experts are able to overcome this limit by fine-tuning connections with adjustments to TCP. This type of "middleware" can help us use existing resources more efficiently.

The **HomeNetToo** project focuses on the home Internet use of low-income families, many of whom are first-time computer users. Internet use is automatically computer-logged and surveys are administered at five times over an 18-month period to address the antecedents and consequences of Internet use. Preliminary findings indicate that cognitive style is related to Internet use and influences the relationship between race and use (as does socioeconomic status, i.e., education and income). Subsequent analyses will identify additional culturally-based factors that influence this relationship. Twenty-three undergraduates served as technology facilitators during the project's first year, nearly half (10) of whom were members of underserved minority groups (nine African-Americans, one Hispanic-American). Almost half (11) were female. All are majoring in Computer Science. The graduate student who served as Project Director in the first year is an African-American male, majoring in educational technology.

Digital archives: Two important NSF-supported tools projects are already available on the web. The first catalogs the development of sanitary technologies for New York during the 19th century in a digital archive of documents, reports, and illustrations. With NSF assistance, the Center for the History & Ethics of Public Health in the Department of Sociomedical Sciences in the Mailman School of Public Health at Columbia University has assembled *The Living City* (http://156.145.78.54/htm/home.htm), which includes among other things, an annotated timeline for New York from the 1860s through the 1920s. This project could become an essential reference tool for historians and students interested in sanitation, technology, urban history, and New York City history.

The other accomplishment is the *Perseus Digital Library* at Tufts University devoted to ancient Greece (http://www.perseus.tufts.edu/). The Perseus project is widely regarded as a model for digital archives.

INDICATOR 3: Information and policy analyses that contribute to the effective use of science and engineering resources.

RESULT: ***Demonstrated significant achievement. Examples follow.***

The Division of Science Resources Statistics (SRS) is the unit within NSF charged with collecting, analyzing and disseminating information on the S&E enterprise. These activities fulfill the legislative mandate of the National Science Foundation Act to ”provide a central clearinghouse for the collection, interpretation, and analysis of data on scientific and engineering resources, and to provide a source of information for policy formulation by other agencies of the Federal Government.”

To carry out this mandate, SRS designs, supports, and directs 11 periodic surveys as well as a variety of other data collections and research projects. These activities yield the materials for SRS staff to compile, analyze, and disseminate quantitative information about domestic and international resources devoted to science, engineering, and technology. Each year SRS produces 40 to 50 publications, ranging from short Data Briefs and Issue Briefs highlighting results from recent surveys and analyses to Detailed Statistical Tables (DSTs) containing extensive tabulated data from a particular survey; and large, comprehensive "overview" reports, such as *Science and Engineering Indicators* and *Women, Minorities, and Persons with Disabilities in Science and Engineering.*

All new publications are placed on the SRS website and some material is available only in an electronic format, not in a printed version. Many tables on the web are also available in a spreadsheet format so they may be downloaded and manipulated by users. The data are also provided to users in a variety of formats, media, and in customized tabulations. In addition, access to much of the data is provided through on-line databases.

SRS has made improving the quality and usefulness of its data a high priority in recent years. In previous years, SRS has had GPRA performance goals related to the timeliness of the release of the data the Division collects and establishment of data quality measures for its surveys. For FY 2001, SRS worked to improve the relevance and quality of the data it collects, the two dimensions rated most important by SRS customers in a 1999 customer survey – accuracy and the ability to find and obtain needed information on S&E personnel and resources.

For FY 2001, SRS identified one or more aspects of each ongoing survey in need of improvement and ways in which such improvement could be pursued. Projects for half the surveys were begun in FY 2001. Choices as to which of the projects to pursue in FY 2001 were based on a variety of factors, including funding, feasibility, favorable timing in terms of the survey cycle, and Division priorities. In nearly every case, these projects will extend into FY 2002 and beyond, and it will be several years before the results of these efforts will be evident in terms of improved data quality. In the meantime, additional projects directed toward improving data quality will be undertaken in FY 2002 and subsequent years.

The projects undertaken in FY 2001 vary considerably in scope, ranging from the complete redesign of the Survey of Scientific and Engineering Research Facilities to

review/improvement of questionnaire layout and specific question wording of several surveys to adoption of a standard method of computing response rates in the National Survey of Recent College Graduates. Examples of specific FY 2001 projects include the Facilities Survey, the Federal Funds Survey, the Academic Survey, the Graduate Student Survey (GSS), and the National Survey of Recent College Graduates (NSRCG)

In addition to these projects, all of which had been identified at the beginning of FY 2001, SRS undertook a variety of other activities during the year that will contribute to improved data quality in the future. Several approaches toward improving questionnaire design (paper and electronic) were started, including cognitive interviews with survey respondents and assistance from a nationally recognized expert on questionnaire design. Specifically, with regard to the public attitudes survey, several avenues were explored as alternatives to the historical Random-Digit-Dialing (RDD) telephone survey, about which there are concerns related to both content and response rates. These included placing items on other surveys, and web-based options for collecting information.

SRS also provided data and assistance to a variety of offices throughout the government in support of policy debates about science and technology. For example, SRS continued working with the Immigration and Naturalization Service in efforts to improve the scope of data capture and nature of coding of immigrants' education levels, major fields, and last occupation before entering the U.S.

In addition to conducting surveys and releasing reports/data based on the surveys, SRS prepared and completed external reviews of the Congressionally mandated report, *Women, Minorities and Persons with Disabilities in Science and Engineering: 2002*, a source book of data on the participation of these groups in science and engineering education and employment, widely used by policy makers addressing the problems of underrepresentation of these groups in science and engineering.

SRS released, on the Division of Science Resources Statistics website, the Industrial Research & Development Information System (IRIS) which is an online interface to the new Survey of Industrial Research and Development Historical Database 1953-1998. The database contains all industrial research and development (R&D) data published by NSF for the years between 1953 and 1998 in over 2,500 statistical tables including statistics on the levels of R&D support from company and federal sources and sales and employment of R&D performers.

Area of Emphasis 1: Investments in Major Research Equipment (MRE).

Examples follow.

NSF provides funding for capital expenditures for the construction and acquisition of major research facilities that provide unique transformational capabilities at the cutting-edge of science and engineering. Projects supported capitalize on technological innovation to provide significant new research and education opportunities, frequently in totally new directions. Continuing projects include South Pole Station Modernization (SPSM), Atacama Large Millimeter Array (ALMA) research and development, Network for Earthquake Engineering Simulation (NEES), the Large Hadron Collider, and the Terascale Computing System (highlighted in the next section).

The **Large Hadron Collider** (LHC) will be the frontier particle accelerator in the world when it comes on-line in the second half of this decade. There is now preliminary experimental evidence that the Higgs particle, the key to understanding why everything in the universe has mass, can be detected with the LHC. Recent work at the Brookhaven National Laboratory on the magnetic moment of the muon, (the recently reported results from the "g-2" experiment), provided results not predicted by the Standard Model. Further tests of the Standard Model will be done at the LHC. The U.S. ATLAS and CMS projects continue to meet their goals and are reliable and influential partners in the construction of the two detectors of the LHC machine. The European Organization for Nuclear Research (CERN) expects to complete construction of the LHC and initiate collider commissioning in 2005. The U.S. schedules are consistent with this goal. The institutions developing the two detectors have done an excellent job of meeting cost and schedule goals.

At 10:00 AM, Friday, October 20, 2000, leaders of the **Laser Interferometer Gravitational-wave (LIGO) Observatory** announced that "First Lock" had been achieved with the two-kilometer long interferometer at the Hanford Observatory. This marked achievement of a major LIGO milestone. All mirrors were "locked" into their proper positions to atomic-scale precision using a sophisticated computer-based control system. First lock validated many aspects of the control system design for the initial LIGO detectors, but it had even greater significance – the beginning of the process of tuning the interferometer to its full sensitivity. Most importantly, this achievement brought LIGO closer to its ultimate goal – the first true gravitational-wave observations.

NSF supports two ongoing MRE projects of enormous significance to scientific and engineering research in the Antarctic region: 1) The **South Pole Station Modernization**; and 2) Polar Support Aircraft (LC-130) Upgrades. Both projects represent essential investments in the health and vitality of on-continent and deep-field research in Antarctica.

Areas of Emphasis 2: Continue investments in Terascale Computing System, Major Research Instrumentation, S&E information/reports/databases; New types of scientific databases and tools for using them.

Examples follow.

Terascale Computing System

NSF is continuing development of a *Terascale Computing System* to enable U.S. researchers and educators to gain access to leading edge computational systems.

- **Supporting technologies:** Research performed under past and present NSF support has been incorporated as key components of the Terascale Computing System in the following key technology areas of parallelizing compilers; sequential compilers; numeric libraries; runtime libraries; and parallel software tools, input/output, visualization, and applications.

- **Initial performance:** The new Terascale Computing System (TCS) funded by NSF in fiscal year 2000 has begun operation well ahead of schedule and is exceeding performance expectations. During an acceptance test in which the Pittsburgh Supercomputer Center staff evaluated its performance, TCS consistently surpassed speed expectations and operated virtually without interruption. The combined peak power of the full computer system will be 6 Teraflops, making it the most powerful computer available to academic scientists and engineers in the United States.

The Major Research Instrumentation Program

The Major Research Instrumentation Program (MRI) is designed to improve the condition of scientific and engineering equipment for research and research training in our nation's academic institutions. This program seeks to improve the quality and expand the scope of research and research training in science and engineering, and to foster the integration of research and education by providing instrumentation for research-intensive learning environments.

- The **Electronic Visualization Laboratory's (EVL)** research has focused on developing tools, techniques and hardware to support real-time, highly interactive visualization. Current efforts continue through the development of virtual reality (VR) devices, software libraries/toolkits and applications for collaborative exploration of data over national and global high-speed networks - called "tele-immersion." After building first and second-generation VR devices [the Cave Automatic Virtual Environment (CAVE) in 1991 and the ImmersaDesk in 1995] to support tele-immersion applications, EVL is now conducting research in "third-generation" VR devices to construct variable resolution and desktop/office-sized displays. EVL continues to develop and refine a robust and VR-device-independent software library, as well as the software tools for building tele-immersion applications. This software infrastructure supports collaboration in design, training, scientific visualization, and computational steering in VR. Through advanced networking techniques, researchers can access distributed computing, storage and display resources more efficiently than ever.

S&E informational/reports/databases

- **The General Social Survey:** The General Social Survey (GSS) has been monitoring social change in the United States, examining sub-groups in society, and studying social processes since 1972. Over this period, 23 cross-sectional surveys of the U.S. adult household population have been completed, involving face-to-face interviews with approximately 41,000 respondents. Surveys document fundamental social change in areas such as uses of technology, social and cultural capital, neighborhoods and communities, social networks, and racial and gender attitudes. The GSS is widely used by the academic research community and scholars at research centers, foundations, and in government. For example, as of April 2000, there were 5,430 documented uses of the GSS data, including 2,676 journal articles, 1,201 books, 959 scholarly papers and 153 dissertations and theses. The GSS is used extensively in teaching, with GSS having been utilized in 226 textbooks and contained in course materials on 224 websites. The cumulative GSS data files are used in the Inter-University Consortium for Political and Social Research (ICPSR) Summer Program, which is annually attended by 150 scholars representing over 100 colleges in the United States and Canada. GSS data are made available to researchers and their students. The GSS Data and Information Retrieval System provides facilities for statistical analyses, hypertext viewing, customized extracts from data sets, and File Transfer Protocol for extracted data sets.

- **Climate Change Policy:** NSF supports scientists who are engaged in the Intergovernmental Panel on Climate Change (IPCC) and U.S. National Assessment programs. The results of both of these assessments are used for policy analyses so that there is effective use of scientific resources. Beyond these scientific assessments with their specific policy-informing goal, there are specific examples of studies that provide policy analyses. One particular example involves an analysis of climate-change abatement policies. Most quantitative studies of climate-change policy attempt to predict a greenhouse-gas reduction plan that will have the optimum balance of long-term costs and benefits. However, it was found that large uncertainties associated with the climate-change problem could make the policy prescriptions of this traditional approach unreliable. An adaptive strategy with mid-course corrections was able to avoid significant errors.

New types of scientific databases and tools for using them

- **Government statistical information** is essential in the day-to-day lives of all citizens. The importance of such data is illustrated by the efforts of multiple federal government agencies to create the National Statistical Information Infrastructure. Data from agencies such as Bureau of Labor Statistics, Census Bureau, and Bureau of Economic Analysis determine costs of everything from apples to zinc, the locations of new businesses, and the indexes for all government programs and payments. Web-based technologies offer citizens broader access to the vast array of statistical data so that they may make better personal decisions. Examples include baby-boomers planning for retirement, unemployed or underemployed individuals looking to relocate, and school children exploring careers. For broader segments of the population to take advantage of government statistical information, however, the data must both be easy to find and easy to interpret and use. Ease of search in this setting depends on helping users articulate needs, on distributing these articulations to different datasets across the federal

government, unifying the results, and presenting them in forms most useful to user needs. NSF-supported researchers have successfully completed work on graphical representation, manipulation, browsing, and usability over the Web for federal statistical (tabular) data. As the system becomes commercially available to the users of federally collected and archived statistical data, the primary challenge is to ensure it will improve the usefulness of data in establishing, for example, the Consumer Price Index, the unemployment rate, and the determination of federal congressional districts.

- **LAPACK and ScaLAPACK:** The LAPACK and ScaLAPACK libraries are the standard software for solving dense linear equations. With FY 1999 funding NSF-supported release 3.0 of LAPACK, which improves error bound estimates. As important as the LAPACK software is the means by which it is disseminated. NSF has been a long-term supporter of Netlib, the standard Internet repository for numerical software. There have been over 129,000,000 requests from Netlib to date, indicating just how popular it is. Less obvious is the amount of effort that its search capabilities have saved countless investigators in locating the right software for the job. NSF support of Netlib also contributes to full use of the national networks (http://www.netlib.org/lapack/index.html), (http://www.netlib.org/scalapack/index.html).

- This year NSF supported the establishment of the **National Historical Geographic Information System** (NHGIS) to upgrade and enhance U.S. Census databases from 1790 to the present, including the digitization of all census geography so that place-specific information can be readily used in geographic information systems. The NHGIS consists of three major components: (1) The data and documentation component will gather all extant machine-readable census summary data, fill holes in the surviving machine-readable data through data entry of paper census tabulations, harmonize the formats and documentation of all files, and produce standardized electronic documentation according to the recently developed Data Documentation Initiative (DDI) specification. (2) The mapping component will create consistent historical electronic boundary files for tracts, minor civil divisions, counties, and larger geographic units. (3) The data-access component will create a powerful but user-friendly, Web-based browser and extraction system based on the new DDI metadata standard. The system will provide free public access to both documentation and data and will present results in the form of tables or maps. Through these activities, the NHGIS will become a resource that can be used widely for social science training, by the media, for policy research at the state and local levels, by the private sector, and in secondary education.